

WITH VOLUME TITLE, CONTENTS AND INDEX TO VOLUME 16
47TH ANNUAL CONVENTION, CHICAGO, ILLINOIS, JUNE 6-11, 1927
VOL. 17, NO. 6 JUN 11 1927 JUNE, 1927

Engineering
Library
PROCEEDINGS 47TH YEAR

JOURNAL OF THE AMERICAN WATER WORKS ASSOCIATION



PUBLISHED MONTHLY
BY THE
AMERICAN WATER WORKS ASSOCIATION
AT MOUNT ROYAL AND GUILFORD AVENUES, BALTIMORE, MD.

SECRETARY'S OFFICE, 170 BROADWAY, NEW YORK
EDITOR'S OFFICE, 16 WEST SARATOGA STREET, BALTIMORE, MARYLAND

Subscription price, \$7.00 per annum

Entered as second class matter April 10, 1914, at the Post Office at Baltimore, Md., under the act of August 24, 1912
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917;
authorized August 6, 1918

COPYRIGHT 1927, BY THE AMERICAN WATER WORKS ASSOCIATION

Made in United States of America

Mathews Fire Hydrants

(REG. U. S. PAT. OFF.)

"THE RECOGNIZED STANDARD"
For Domestic or High Pressure Service

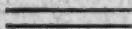
FROST PROOF---AUTOMATIC POSITIVE DRAIN
CORRECTLY DESIGNED---RUGGEDLY CONSTRUCTED
FEW PARTS---MINIMUM UPKEEP AND REPAIR



An easily installed

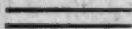
EXTENSION SECTION

and the outer casing make Mathews Hydrants readily adaptable to new grades and conditions.



GATE VALVES

For All Purposes



VALVE BOXES--INDICATOR POSTS
CAST IRON PIPE

(Sand-Cast or "Sand-Spun" Centrifugally Cast)

FITTINGS

R. D. WOOD & CO.
PHILADELPHIA, PA.

SALES OFFICES

Worcester, Mass.
Petersburg, Va.
Lake Worth, Fla.
Dallas, Texas

Chicago, Illinois
Cleveland, Ohio
San Francisco, Cal.
Los Angeles, Cal.

Notice!

All correspondence relating to the publication of papers should be addressed to the Editor, Abel Wolman, 16 West Saratoga Street, Baltimore, Maryland.

Fifty reprints, without covers, of articles will be furnished to contributors free of cost, provided a request therefor is made in writing. Additional reprints may be purchased.

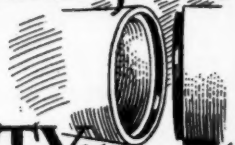
HUSKY water pressures always



call for **PIPE** of impervious concrete. For am-



ple reinforcement and **FOR** efficient joints



to meet the ever-**THIRSTY** demands



of the water-wasteful **CITIES**

the above clearly indicates

Pressure
Sewer
Culvert
Centrifugal
Subaqueous

LOCK JOINT
Reinforced
Concrete Pipe

Lock Joint Pipe Co.
Established 1885
14 Rutledge Ave.,
Ampere, N. J.



JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

VOL. 17

JUNE, 1927

No. 6

CONTENTS

Protecting the Water Supply System in Subway Construction in New York City. By Robert Ridgway....	629
Charges for Public Fire Protection. By R. L. Dobbin....	647
Experiments in Hydraulics of Filter Underdrains. By N. Malishevsky.....	667
A General Rule for Making Extensions. By R. E. Duffy.....	673
Continuous Versus Periodic Reading of Meters and Billing. Topical discussion.....	683
Experiences with Storage Reservoirs at Low Levels. By William W. Brush.....	699
Preliminary Experiments on the Treatment of Lake Michigan Water for Chicago. By John R. Baylis.....	710
Flood Control in the Miami Valley of Ohio. By C. S. Bennett.....	727
Use of Two Water Mains in Wide Streets. By Thomas F. Wolfe.....	740
The Water Supply Problems of Tennessee. By Howard R. Fullerton.....	746
Water Softening as an Adjunct to Water Purification. By Charles P. Hoover.....	751
Typhoid Fever in the Large Cities of the United States in 1926.....	760
Abstracts.....	771
Society Affairs.....	787



OFFICERS OF THE AMERICAN WATER WORKS ASSOCIATION

President

ALLAN W. CUDDEBACK, Engineer and Vice-President, Passaic Water Co.,
158 Ellison St., Paterson, N. J.

Vice-President

JAMES E. GIBSON, Manager and Engineer, Water Department, 14 George St.,
Charleston, S. C.

Treasurer

WILLIAM W. BRUSH, Deputy Chief Engineer, Division of Water, Department
of Water Supply, Gas and Electricity, Municipal Building,
New York, N. Y.

Secretary

BEEKMAN C. LITTLE, 305 Cutler Building, Rochester, N. Y.

Editor

ABEL WOLMAN, 16 West Saratoga Street, Baltimore, Md.

Trustees

Term expires 1927	Term expires 1928	Term expires 1929
EDGAR M. HOOPES, JR. Wilmington, Del.	R. L. DOBBIN Peterborough, Ont.	F. E. BECK Utica, N. Y.
J. ARTHUR JENSEN Minneapolis, Minn.	GEORGE H. FENKELL Detroit, Mich.	J. O. CRAIG Salisbury, N. C.
FRED MORSE RANDLETT San Francisco, Cal.	PATRICK GEAR Holyoke, Mass.	THEODORE A. LEISEN Omaha, Nebr.

Executive Committee.—ALLAN W. CUDDEBACK, JAMES E. GIBSON, BEEKMAN C.
LITTLE, WILLIAM W. BRUSH, ABEL WOLMAN, GEORGE C. ANDREWS, HARRY
F. HUY, FRANK C. JORDAN and the nine Trustees.

Finance Committee.—GEORGE C. ANDREWS, Chairman; CHARLES R. BETTES,
E. G. WILHELM.

Publication Committee.—MALCOLM PIRNIE, Chairman; C. A. EMERSON, JR.,
Vice-Chairman; BEEKMAN C. LITTLE, Secretary; ABEL WOLMAN, Editor;
JAMES W. ARMSTRONG, A. M. BUSWELL, F. G. CUNNINGHAM, W. W. DE-
BERARD, JAMES E. GIBSON, JOHN M. GOODELL, NICHOLAS S. HILL, JR.,
FRANK C. JORDAN, JOHN F. LABOON, JAMES J. SALMOND, STEPHEN H.
TAYLOR.

Officers of the Divisions

Water Purification Division.—Chairman, NORMAN J. HOWARD; Vice-Chair-
man, WELLINGTON DONALDSON; Secretary, HARRY E. JORDAN; Executive
Committee, JAMES W. ARMSTRONG, PAUL HANSEN, CHARLES G. HYDE.

Fire Protection Division.—Chairman, NICHOLAS S. HILL, JR.; Vice-Chairman,
ALLAN W. CUDDEBACK; Secretary-Treasurer, CLARENCE GOLDSMITH.

Plant Management and Operation Division.—Chairman, W. S. PATTON;
Vice-Chairman, DOW R. GWINN; Secretary-Treasurer, GEO. C. GENS-
HEIMER; Trustees, W. S. CRAMER, ALEXANDER MILNE.

OFFICERS OF THE AMERICAN WATER WORKS ASSOCIATION (Continued)

Officers of the Sections

- California Section.*—Chairman, SAMUEL B. MORRIS; Vice-Chairman, J. R. RYLAND; Secretary-Treasurer, PAUL E. MAGERSTADT; Executive Committee, JOHN BURT, P. DIEDERICH, and the officers.
- Canadian Section.*—Chairman, D. McLEAN HANNA; Vice-Chairman, J. O. MEADOWS; Secretary-Treasurer, A. U. SANDERSON; Immediate Past Chairman, R. H. STARR; Trustees, W. E. MACDONALD, W. C. MILLER, MARCEL PEQUEGNAT; Representative of Canadian Water Works Equipment Association, J. J. SALMOND.
- Central States Section.*—President, CHESTER F. DRAKE; Vice-President, MENTOR HETZER; Secretary, E. E. BANKSON; Trustees, D. C. GROBBEL, C. P. JAEGER, C. H. WETTER.
- Florida Section.*—Chairman, ANSON W. SQUIRES; Vice-Chairman, EUGENE MASTERS; Secretary-Treasurer, E. L. FILBY; Directors, term expiring 1927, C. C. BROWN, A. P. MICHAELS; term expiring 1928, L. B. DUANE, W. A. RICHARDS; term expiring 1929, F. W. LANE, F. J. STEWART.
- 4-States Section.*—President, SETH M. VAN LOAN; Vice-Presidents, V. BERNARD SIEMS, L. VAN GILDER; Secretary-Treasurer, CHARLES R. WOOD; Executive Committee, N. E. BARTLETT, W. H. BOARDMAN, H. D. BROWN, J. W. LEDOUX, GEORGE MCKAY, and the officers.
- Illinois Section.*—President, G. C. HABERMAYER; Vice-President, C. M. ROOS; Secretary, M. L. ENGER; Treasurer, H. E. KEELER; Trustees, H. M. ELY, W. R. GELSTON, L. R. HOWSON.
- Indiana Section.*—President, J. W. MOORE; Vice-President, C. E. STEWART; Secretary-Treasurer, C. K. CALVERT; Assistant Secretary-Treasurer, L. S. FINCH; Executive Committee, E. W. AGAR, HARRY GARMAN, J. W. JOPLIN, F. C. JORDAN, WM. LUSCOMBE, J. B. MARVIN, H. S. MORSE, F. P. STRADLING, W. L. YOUNCE.
- Iowa Section.*—Chairman, J. W. McEVoy; Vice-Chairman, THOMAS J. SKINKER; Secretary-Treasurer, JACK J. HINMAN, JR.; Directors, W. SCOTT JOHNSON, JOHN W. PRAY.
- Kentucky-Tennessee Section.*—Chairman, W. S. PATTON; Vice-Chairman, F. W. ALBERT; Secretary-Treasurer, F. C. DUGAN; Directors, S. R. Blakeman, W. H. LOVEJOY.
- Minnesota Section.*—Chairman, FELIX SELIGMAN; Vice-Chairman, G. C. PRUETT; Secretary, R. M. FINCH; Trustees, OLE FORSBERG, A. D. HORNE, WILLIAM TODD.
- Montana Section.*—President, JOHN W. HALL; Vice-President, JOSEPH M. SCHMIT; Secretary-Treasurer, HERBERT B. FOOTE.
- New York Section.*—President, F. T. KEMBLE; Secretary, E. D. CASE; Board of Governors, F. E. BECK, E. D. CASE, F. T. KEMBLE, WM. A. McCAFFREY, THADDEUS MERRIMAN.
- North Carolina Section.*—President, C. M. GRANTHAM; Vice-President, C. E. RHYNE; Secretary-Treasurer, H. G. BAITT; Executive Committee, H. G. BAITT, G. F. CATLETT, J. O. CRAIG, C. M. GRANTHAM, E. G. McCONNELL, H. E. MILLER, C. E. RHYNE, W. E. VEST.
- Rocky Mountain Section.*—Chairman, PAUL E. STROUSE; Vice-Chairman, L. C. OSBORN; Secretary-Treasurer, DANA E. KEPNER; Directors, term expiring 1928, D. V. BELL, PAUL S. FOX, term expiring 1929, E. C. GWILLIM, C. CICERO OGLE; term expiring 1930, E. A. LAWVER, A. W. STEDMAN.
- Wisconsin Section.*—Chairman, JOHN KUESTER; Vice-Chairman, ARTHUR J. HALL; Secretary-Treasurer, LEON A. SMITH; Director, H. W. JACKSON.

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings
Discussion of all papers is invited

VOL. 17

JUNE, 1927

No. 6

PROTECTING THE WATER SUPPLY SYSTEM IN SUBWAY CONSTRUCTION IN NEW YORK CITY¹

BY ROBERT RIDGWAY²

A wholesome water supply in abundance and an adequate local transit system are essential to the well-being and healthy growth of a large city. Both are of major importance to the communities they serve. It is not necessary to point out to water works men the importance of a water supply. Without it, the city could not exist. New York is blessed in this respect, thanks to men of vision and ability like those who have just addressed you. But transit is of primary importance, and the task of those responsible for it is a difficult one. If transit does not keep pace with the need for it, the city's growth and development are seriously impaired. I suppose we shall never catch up in this city. Car riders increase in number about as the square of the increase of population, and it is difficult to provide facilities at this rate, especially as each new transit line has a way of costing more than its predecessors. If subways ever catch up with the need for them, we will need a large addition to the water supply to provide for the great increase in population that will follow.

The water supply engineer has one advantage over his brother in the transit field, in that most persons assume that his work is well

¹ Presented before the New York Section meeting, December 29, 1926.

² Chief Engineer, Board of Transportation, New York, N. Y.

done, and pay little attention to him unless a main breaks, or a "Committee on Rumors" reports that a mysterious hole has appeared in the impervious bottom of a reservoir. On the other hand, every car rider is interested in transit, because he uses the lines every day and is familiar with their shortcomings and defects. Naturally his criticisms are not always just or constructive.

It is difficult in a large city like this for all interests to unite on a transit plan. When the latter is finally adopted it is the result of the workings of many minds and interests. Just now we are building a new subway system in New York which is to traverse Manhattan and extend into three of the remaining four boroughs of the city, Richmond being the exception. As an example of the cost of subway construction today, it is estimated that the 57 miles of route with its 170 miles of single running track will cost to construct and equip, including engineering, administration and cost of money during construction, about \$600,000,000. The main four-track trunk of the system in Manhattan is on the west side, extending from 207th Street and Broadway to Fulton Street, thence under the East River to Brooklyn. In the middle section of the city it is located under Eighth Avenue.

When William Barclay Parsons designed the first subways built in this city a quarter of a century ago, after careful consideration of the whole matter, he decided to build them, wherever the topographical conditions would permit, as close to the street surface as practicable. This was a wise decision for a number of reasons—among others, it reduces the climbing at stations, avoiding the use of escalators and elevators, this making for convenience and economy. This general plan is still believed to be the preferable one, and is being followed today. It has, of course, objections which would not apply to deep tunnel construction. During the construction period it requires the tearing up the streets which interferes with the street traffic, means much readjustment of the subsurface utilities, and introduces hazards of construction to provide for which expensive safeguards are necessary. Perhaps the time is not far away when deep tunnel construction will be used for future subways in Manhattan, because with the many that are now here, it is necessary to go quite deep with the new structures wherever the latter have to pass under existing ones,—in some cases to the third level below the street. The deep tunnel, however, would not be a simple thing to construct. It would be difficult to excavate a cavern in the rock large enough for

a four-track station under a city street, and more difficult if the material was saturated sand. Then to handle the rush-hour crowd in stations far below the surface would require the installation and operation at a great expense of large batteries of large elevators.

SUBWAY CONSTRUCTION AND SUBSURFACE UTILITIES

If the building of a subway was merely the digging of a trench, erecting the structure and backfilling and restoring the street surface, the task would be difficult enough, but added to this is the care of the buildings adjacent, a large percentage of which require expensive underpinning, and the maintenance, support, and restoration of the hundreds of miles of subsurface utilities, such as water mains and steam mains, sewers, telephone and electric light cables. The direct and indirect cost to the city for the care of these subsurface utilities, exclusive of the underpinning of the buildings averages probably 15 per cent of the cost of the subway construction. As an example of how these costs run up, the expense of restoring the telephone and Edison cables on the half mile of subway under Eighth Avenue between 111th and 121st streets, exclusive of the cost of laying the ducts, is about \$285,000. In this stretch, there are about 20 miles of telephone cables alone to be redrawn.

Before the work is placed under contract, a careful survey is made of the subsurface conditions, as far as it is possible to do so, and the information is plotted on a scale ten feet to the inch, the drawings being furnished to the bidders. Of course, the information cannot be guaranteed, but it is generally correct. Incidentally, the work of preparing the information for the bidders is quite burdensome because of the complicated subsurface conditions.

The New York subways are generally of the two-track or four-track type. Normally all tracks are at the same level, but frequently where economy of construction will result, the structure is double decked. Under Central Park West, for example, the four-track subway now being constructed is of the double-deck type, the upper tracks being for northbound traffic and the lower ones for the southbound traffic. The typical four-track subway railroad which we are building has an overall width of about sixty feet and a height of about seventeen feet. There are many variants from this type determined by local conditions and connections to be made with existing railroads.

In general, subways are located as near to the street surface as is

practicable to reduce the amount of excavation. In this matter, we are governed by the underground structures which are encountered. As a rule we endeavor to have 6 feet of cover over the subway roof and follow generally the grade of the street surface. But on account of the presence of existing subways or important underground structures which have to be crossed or because the grades of the streets are greater than can be used on tracks, or when the subway approaches rivers under which it is to be carried, greater depths of cover are secured which may at times be so deep that tunneling is used. It is evident, therefore, that with the shallow type of subway which we are building, serious interference results with the underground structures, such as gas mains, ducts for lighting and telephone cables, water mains, steam mains, pneumatic tubes and sewers, requiring at times radical rerouting and rearrangement of these structures. Next to ducts with the cables within them and sewers, the greatest difficulty and expense is entailed with water mains. These normally have four feet of cover and most of them vary in size from 12 inches to 48 inches in diameter, and, therefore, with about 6 feet of cover over the subway roof, interference with the larger water mains often results. This is particularly the case at street intersections where the structures on the avenue and on the intersecting streets occupy different levels.

CARE OF WATER MAINS IN SUBWAY CONSTRUCTION

Every engineer and contractor engaged in subway construction has a wholesome respect for the water main and realizes that a break, especially in one of large calibre, means trouble and damage; therefore, every precaution is taken to support them properly and they are carefully watched, a caulker being on hand to correct any small leak that may occur. A 48-inch water main is looked upon with the same degree of respect as is a dynamite magazine, and is believed to have about the same potential power for damage if it should "let go." The damage cannot be lightly regarded because breaks have occurred from time to time which have flooded the construction workings and, on several occasions, the operating subways with serious results. If it could be done, subways would be kept away from these large mains, but that is not possible.

The manner of supporting five 48-inch mains on Central Park West which lead from the Catskill Aqueduct shaft in the Park at 106th Street is shown in figure 2. I-beams spanning the pipes

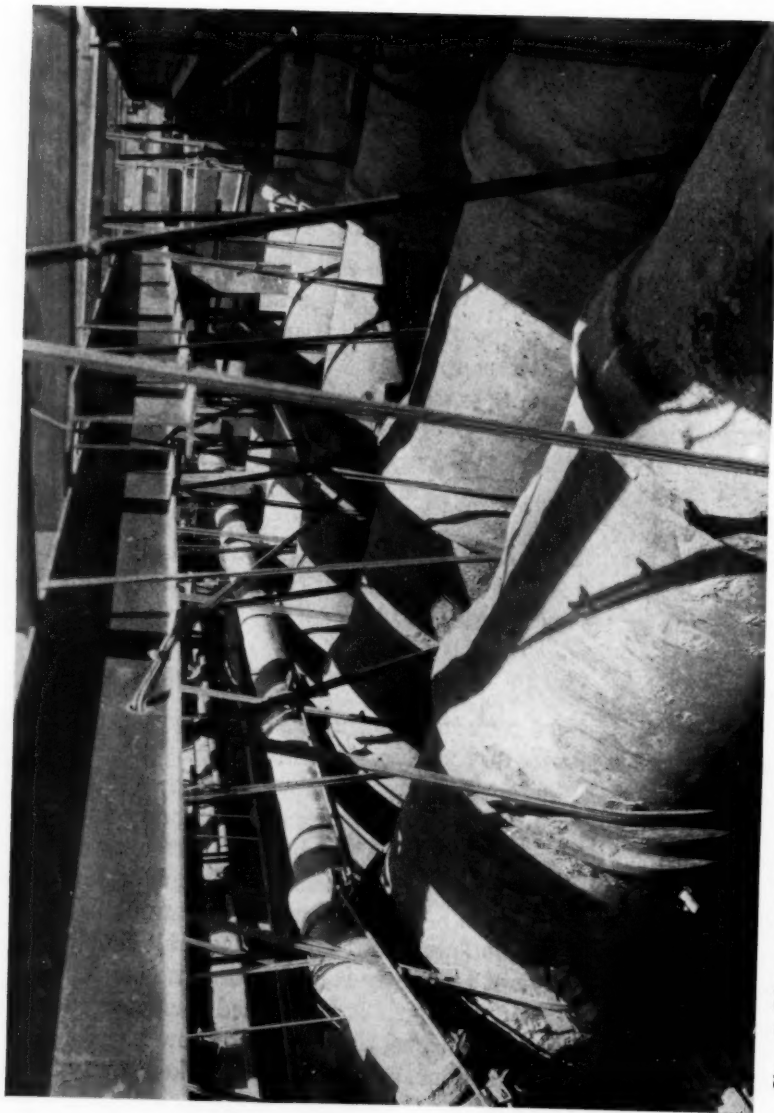


FIG. 2. METHOD OF SUPPORTING FIVE 48 INCH CAST-IRON WATER MAINS ABREAST IN A PORTION OF
THE SUBWAY CUT IN CENTRAL PARK WEST

were supported on the street surface, and the pipes were hung from them by means of wire cables guyed in several directions to prevent lateral movements as well as vertical settlement of the pipes while the rock was blasted and removed below them. These supporting beams were an obstruction to the street surface, but it was considered better to endure this inconvenience than to risk supporting the pipes from below as it was feared that the blasting might knock the supports out with disastrous results. We will all be glad when these five pipes are permanently supported on the subway roof. This is but one of many interesting details of water main support which can be seen along the line of the work.

Along the line of the new subway now being built in Manhattan from Fulton Street to Washington Heights, a length of about fifteen miles, there exist about three miles of high pressure water mains and about thirty miles of low pressure mains ranging in size from 6- to 48-inches. The high pressure mains extend only as far north as 34th Street. Not all of these mains are interfered with, but most of them have to be supported, relocated or even replaced in their new positions with new mains. In some instances the water mains have to be rerouted through different streets.

GENERAL CARE OF WATER MAINS

Where new mains have to be laid, they are made to conform to the standards and requirements of the Department of Water Supply. Recently in cooperation with that department we have been using steel pipe more extensively than heretofore for the larger sized main. This has been done to reduce failures in pipes which, it is feared, might occur where mains are laid in disturbed material or fill. Cast-iron pipe, if subject to excessive stress, fails without warning, whereas steel will deform without failure. Cast iron mains fail suddenly and cause a great deal of damage, whereas steel pipe gives warning of deterioration by leaks through cracks or pinholes which have developed, so that it can be repaired before any material damage has resulted. The repairs of cast-iron pipe must be done at once when the failure has occurred, which always prove expensive. Steel pipe can be repaired after the situation has been studied, if the leakage is slight, and the repairs can therefore be made more economically.

The construction contracts make suitable provision for the care of the water mains and other utilities and the requirements concerning them are clearly outlined there and in the drawings. Further pro-

visions are made in the new contracts to avoid failures of water mains where laid in backfill. At such locations the mains, whether of steel or cast-iron, will be supported from either the subway roof or undisturbed material by means of a concrete cradle carried on a reinforced concrete trestle, consisting of a floor with piers about ten feet apart.

Where the cover of the subway is small or the main is large, it is necessary to carry the main through a depressed bay in the subway roof with a vertical reverse curve at each end. If the top of the pipe is less than three feet from the surface the pipe is protected against shocks from roadway loading by means of a reinforced concrete slab above it carried by a pier on each side of the pipe reaching to the subway roof.

WATER SERVICES

Ventilating chambers are provided for the subway at comparatively frequent intervals which lead from the subway roof to the sidewalks or park areas where the openings are covered with gratings. These interfere at times with the various services to buildings. At intervals spaces called "blind bays" are left between the ventilating chambers so that most of the services can be kept outside and independent of the railroad structure. At times this is not possible. In such cases ferrules are provided through the ventilator chambers through which the services are carried. With water services through ventilators, additional precautions are necessary to prevent freezing from exposure to the atmosphere in severely cold weather. After an exhaustive investigation carried on in a cold storage place checked by calculation, a design was developed for protecting exposed water service from freezing. This consists of increasing the water service to a minimum size of two inches carried through a ferrule covered with three layers of one inch hair felt and tar paper, the whole protected with an outside ten-inch steel ferrule. This construction is extended at least two feet into the adjoining ground on each side of the ventilating chamber.

LOCATION OF CENTRAL PARK WEST SUBWAY

Between 59th and 110th Streets the new subway is under Central Park West. In this stretch we have encountered about 30,000 feet of water mains, of which about 8800 feet are 48-inch, 3800 feet are 36-inch, and 4200 feet are 30-inches in diameter; the remaining pipes

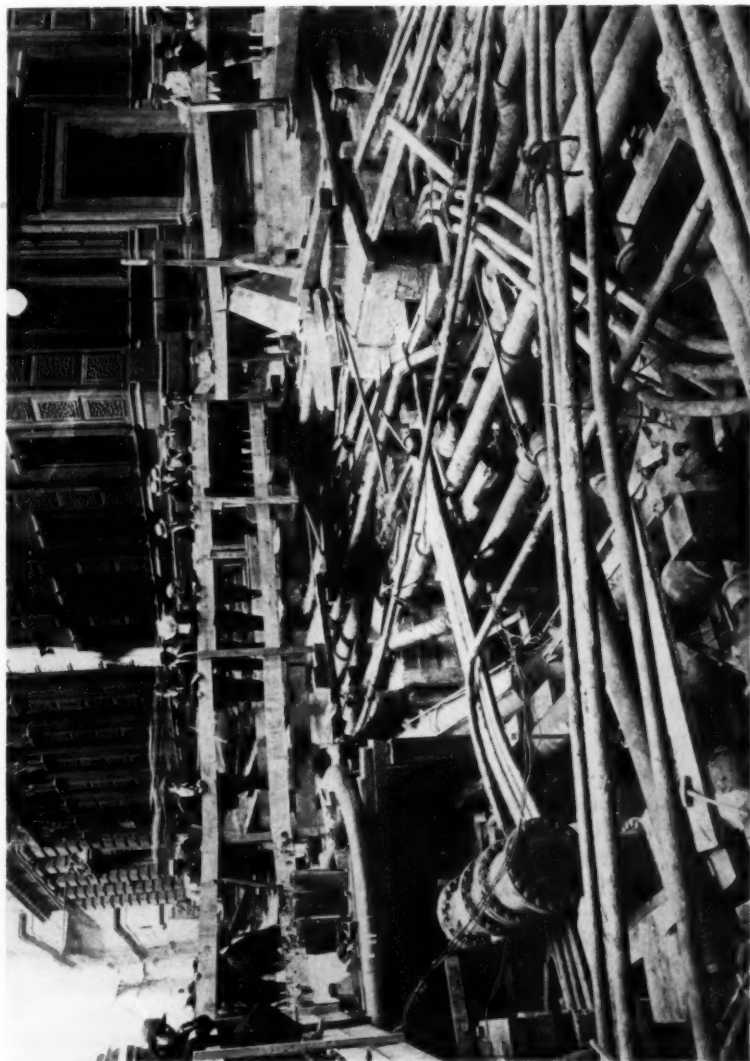


FIG. 3. COMPLICATED SYSTEM OF PIPES BENEATH STREET SURFACE ENCOUNTERED IN SUBWAY EXCAVATION IN WILLIAM STREET AT THE CORNER OF WALL STREET

vary from 12- to 20-inches. The subway structure in this location was designed and located with particular reference to the existing water mains. The subway was made of two levels, each having two tracks to reduce the width of the structure, thus avoiding as far as possible interference with the mains; north of 94th Street the railroad was located on the west side of the Avenue because there are four to five 48-inch mains on the east side between 100th and 106th Streets. South of 92nd Street the subway was located on the east side of the Avenue because then the water mains and underground structures lie mostly on the west side. North of 106th Street the subway was gradually changed from two levels to one level and was continued north of 110th Street in Eighth Avenue rather than turning to the west, because of the existence of six 48-inch water mains in Manhattan Avenue, one block west of Central Park West.

72-INCH CAST IRON PIPES IN CENTRAL PARK WEST

In Central Park West, between 85th and 90th Streets, two abandoned 72-inch cast-iron pipes were uncovered by the subway excavation. These pipes originally led from the gate house at about 92nd Street and Columbus Avenue to the Central Park Reservoir, and gave considerable trouble. They were finally replaced with three 48-inch cast-iron pipes, two in Central Park West and one in 85th Street.

Mr. Edward Wegmann in his "Water Supply of the City of New York," pages 77 and 78, gives the following account of these pipes:

Change of the aqueduct from 85th to 92nd Street. An act passed by the Legislature in 1865 obliged the Croton Aqueduct Department to remove the masonry conduit from 85th to 92nd Street (where it was considerably above the level of the adjoining lots and interfered with the grading of the streets) and to substitute for the same iron pipes laid below the ground, or a depressed masonry aqueduct. This measure, which had been contemplated for some years, had been steadily opposed by the Croton Water Board which claimed that all damages caused to the lots through which this high part of the aqueduct passed had been paid for when the work was constructed. At that time, however, no person anticipated the wonderful growth of the city. The change, although expensive, was a great improvement. The masonry conduit was torn down, within the limits mentioned above, and replaced by two lines of cast-iron mains, 6 feet in diameter, which were located as shown on Plate 10. The connections of the masonry conduit with the pipes were made by suitable masonry chambers.

The contracts for the materials and work were made in the latter part of 1864, and the work was commenced in 1865. The pipes were furnished by S.

Fulton and Company, of Philadelphia, and R. P. Parrott, of the West Point Foundry. The contract for grading the line and for laying the pipes was awarded to F. L. Brown and John Wetherell, of New York.

The cost of making the change was estimated at \$310,000, but exceeded this amount on account of the breaking of some of the pipes when subjected in the summer of 1867 to water pressure for the first time. Out of 480 pipes, eighteen were cracked at the hub and one at the spigot end. The cracks varied in length from 2- to 33½ inches, with the exception of two which were respectively 3 feet, 8½ inches and 8 feet 9 inches long. They varied in width from a merely perceptible line to ¼ inch. The cracks occurred invariably for their whole length in or near the center of the bottom of the pipe. The broken mains were repaired by cutting off the hubs and pipes, as far as the cracks extended, replacing them by strong cast-iron sleeves (see figure 16 and plate 10), and, where required, by short lengths of pipe.

Various theories were advanced to account for this failure. The facts in the case were fully discussed by Mr. A. W. Craven, at the time Chief Engineer of the Croton Aqueduct Department, in a paper read before the American Society of Civil Engineers on January 29, 1868. Mr. Craven inclined to the opinion that the failure was due to water-ram caused by shutting the inlet-gate, while the outlet of the pipes was closed. It does not seem, however, that any great water-ram could have occurred. The maximum "head" was only 14.54 feet; the inlet-opening had an area of 2½ square feet, while the area of the two 6-foot pipes was 56.5 square feet. Great care was taken in filling the mains. In the paper mentioned above Mr. Craven states:

"Whatever be the real cause of this failure, I am convinced that if large pipes must in any case be used, an alteration should be made in their shape. If again obliged to use pipes of this caliber under similar circumstances, I would increase the thickness to 2 inches. This would diminish the chance of injury during the cooling of the metal. I think, also, that in pipes of very large size additional security would be ensured by dispensing with the hub or bell ends, and using sleeves as the means of making the joints."

The 6-foot pipes which were laid at the place in question had a thickness of only 1½ inches. The foundations upon which they were placed consisted principally of street embankments into which large stone and earth had been dumped without any special care. Mr. Craven states, however, that no settling of any account had occurred when the failure took place, and that some of the pipes ruptured had been laid on rock. Breaks in the 6-foot mains continued to occur until finally the Department of Public Works replaced these pipes by three lines of 4-foot mains.

WATER MAINS WITHIN THE SUBWAY

Efforts to avoid carrying water mains within the subway railroad have succeeded in all cases, excepting in the old subway under Lafayette Street at the Spring Street and Bleecker Street Stations. This subway was built at these locations with very little cover over the subway and little clearance on the sides of the stations to the

building lines so that the 36-inch water main in this street was located under the east platforms of both the Spring and Bleecker Street Stations. Diverting the main through another street was considered too expensive. Breaks have occurred in this 36-inch main at various points at the normal depth with about 4 feet of cover over it. No breaks have ever occurred in the portions under the platforms. In about 1910 the water mains under the platforms were strengthened by surrounding them with concrete to reduce the danger of a break and consequent subway flooding which would be most serious. In the early part of 1921 an additional gate was installed on this main at Broome Street, making it possible to shut down the main under the stations by closing eight valves whereas previously at least fifteen valves had to be operated. In connection with the break of the main on this line on April 23, 1921, it was necessary to close seventeen valves which took eighty minutes. Additional valves must be closed to relieve pressure on the main gates. The main under the platform has a solid bearing and no concern is felt by the Department of Water Supply for its safety.

In Greenwich Street, between Liberty and Dey Streets, a 20-inch pipe pressure water main was located close to the building line on account of the lack of cover over the subway structure. This pipe was strengthened by surrounding it with reinforced concrete to minimize danger of breaks and thus safeguarding the buildings and their foundations.

CROTON AQUEDUCT

The old Croton Aqueduct has been encountered on the new subway at two points—at St. Nicholas Avenue, 153rd to 154th Streets, and at Central Park West at 92nd Street. The old aqueduct was built of brick and rubble masonry, horse-shoe in sections, 8 feet 5½ inches high by 7 feet 5¼ inches wide. This is being replaced at the points of interference across the subway roof by 96-inch steel pipe, ¾ inches thick, lined with 4 inches of cement mortar and enveloped with about 8 inches of concrete. The grade of the subway was kept down to permit this construction over it. The new masonry section connecting the steel pipe with the old undisturbed aqueduct will be of reinforced concrete of the same interior dimensions as the old aqueduct. About 360 feet of new aqueduct are required, of which about 100 feet are steel pipe as described. The *new* Croton Aqueduct in Amsterdam Avenue at 162nd Street and St. Nicholas Avenue is a

circular masonry lined pressure tunnel 12.25 feet in diameter and has a depth of cover over it of about 140 feet. The new St. Nicholas Avenue subway now under construction crosses over it without interference, the depth of the subgrade being somewhat less than 50 feet.

CATSKILL AQUEDUCT IN MANHATTAN

The depth of the Catskill Aqueduct is so great that the subway workings do not approach it, but do approach several of the shafts. At such points the subway was located so as not to interfere with them. The drains from these shafts which discharge into the nearby sewers have had to be relocated on account of subway interference.

In Brooklyn and Queens, considerable study has been given in fixing the relative locations of the Catskill steel conduits and the subway structures. The steel conduits vary in size from 48- to 72-inches in diameter.

In Queens along East Avenue a 72-inch steel conduit was located under the sidewalk of East Avenue and Jackson Avenue to allow room for a future subway. In Ely Avenue the conduit was terminated near Nott Avenue on account of a proposed subway in this Avenue. The conduit in East Avenue was built as an inverted siphon under the existing I. R. T. subway in 4th street.

PRECAUTIONS WITH GAS MAINS IN SUBWAY CONSTRUCTION

The contracts for subway construction require that the streets be decked so that the usual traffic can be carried on over the excavation. After the pavement is taken up, and the first shallow cut made, the decking is placed, the remainder of the work being carried on under this deck. Before the decking is placed, however, a temporary by-pass gas system is installed, the service mains being laid in the gutters and the house connections carried to them. The larger mains are carried on trestles over the sidewalk or in special locations on the sidewalk. It is the inflexible rule to have no live gas mains under the street decking. This by-passing system is a considerable item of expense, but it is justified on the ground of public safety.

SUPPORTING SUBSURFACE UTILITIES

As the excavation is made it is necessary, of course, to support the subsurface utilities encountered and the timbering of the trench is

designed with this in view. Usually the sewers are broken out and spiral riveted pipe substituted for them. The water, gas, and steam mains are supported on the temporary timbers or steel supports. The telephone and electric light ducts are broken away, and the cables are either boxed or carried in some other way that will preserve them from injury so far as practicable. The contracts require that all of these utilities be maintained in a condition to furnish their usual service, and to the credit of the contractors it should be said that there has been little cause for complaint in this respect. It is very unusual for any service to be out of commission. The contractors have developed many interesting and efficient methods of support.

In the course of subway construction during the past twenty-five years, hundreds of miles of water mains have been exposed. When the work was begun in 1900, it was the idea of others besides myself that we would discover wholesale leaks in these mains, and that seemed to be the general impression at the time. These wholesale leaks were not found and based on an experience covering over a quarter of a century, I have a great respect for the engineers past and present who installed the water mains underlying the streets of New York. The leaks disclosed in our excavations have been remarkably small in number and amount. I think this is an excellent showing, considering the fact that the mains were laid by many men at many times, covering a period of sixty years or more. The standards of the department must have been good standards to achieve such results.

I wish to acknowledge my indebtedness to S. D. Bleich, Assistant Division Engineer of the Board of Transportation, for his assistance in getting the facts for this talk. Mr. Bleich acts as Designing Engineer in charge of the studies for rearrangement of the sewers, water mains, and other subsurface utilities with which the subway construction interferes. He has a high standing with us as an expert in such matters.

DISCUSSION

WM. W. BRUSH:³ Mr. Ridgway was first a water supply engineer then became a subway engineer. He is, as we all know, a very competent engineer in both fields and very sympathetic to the water

³ Chief Engineer, Department of Water Supply, Gas and Electricity, New York, N. Y.

supply problems in his present field of subway engineering. He has gone to great length to devise methods of supporting the water mains during construction, and after the subway is constructed to prevent those mains from settling and breaking.

The supports shown indicate that an effort is being made to make the span between points of rigid and sufficient support a safe span for the water main. There certainly does not seem to be a sound reason for putting a water main in the ground, later disturbing the foundation under that water main, and then backfilling with material that you know beforehand will settle and trust that your large factor of safety in a water main will be sufficient to meet the stress that will come from settlement. Under the present construction of subways, these mains are supported rigidly and adequately as they pass over or along the subway route and then in intermediate disturbed ground are safely carried to the original earth that has not been in any way disturbed. That plan will make for safer construction, will undoubtedly reduce very substantially the breaks, and represents an advance in the art of supporting the water mains after the subway is constructed.

Mr. Ridgway showed the method of protecting services against freezing. Those of you who have the problem of protecting service pipes will obtain very interesting and helpful data if you should ask Mr. Ridgway to furnish you with the information that was obtained and recorded as a result of the extensive tests that were made and experiments carried on by the Board of Transportation or its predecessor under Mr. Ridgway's direction. I think those are the most helpful tests that we have in the water works field for protecting service pipes from freezing.

The subway contractors may have unbounded respect for the water mains, but they blow them out every once in a while, not intentionally, but you cannot control the men who are trying to get the rock out quickly and economically. We depend upon the subway force to see that the water mains are safeguarded and that the valves are not operated. We have only a general inspection by our force. The construction engineer on the subway is primarily interested in getting the subway built, and I think he is conscientious in his attempts to see that the water mains are protected; but it is very difficult when you are working underground to see that somebody connected with the contractors does not operate a gate when he is supposed to leave the gate alone, or that he does not blow

out a water main when he is supposed to see that the water main is adequately protected from the rock that may be dislodged by a charge.

Building subways is a big job. We cannot expect the rock to be taken out piecemeal by channelling, wedging, or barring because that represents a big cost to the city of New York. It is better to lose a water main once in a while than it is to subject the city to the very large cost that would result from attempting to carry on the work without blasting in the vicinity of water mains.

ALEXANDER POTTER:⁴ I should like to ask Mr. Brush a question. In pictures shown on the screen a veritable net-work was indicated of pipes and water mains, probably laid at different times. Has there been any effort made to remove a number of those pipes and replace them by larger mains so as to occupy less area of the street?

WM. W. BRUSH:³ There has not been a very extensive effort made to do so. As a rule we only have one service main in the street, unless it is a case of where a 12-inch or larger main was laid to replace a small main that had failed to be sufficient to meet the needs of that particular area, and where the old main was left in and to be removed when the street is repaved. We do try, with the help of the transportation engineers, to simplify our water supply system when subways are built; and when the mains are relaid, they are relaid in the manner that will reduce to a minimum the number of mains in the street, but usually where there are two or more mains in a street each main has a specific use which would not be served if we took out the two, three or four, as the case may be, and substituted one or more larger mains.

In New York, our plan is to have every trunk main in the city one that can be taken out of service in case of need and left out of service for a period of several days or weeks without any serious impairment as to pressure or fire protection. We have a very serious problem that might develop due to our depending upon the integrity of the Catskill tunnel within the city limits for the greater part of the supply to all of the boroughs. The Board of Water Supply has been working on that problem to furnish a second tunnel so that we will have a substitute and in part an addition to our carrying capacity that will take care of present needs and some of the prospective future needs.

⁴ Consulting Engineer, New York, N. Y.

ROBERT RIDGWAY:² As far as the subway construction is concerned there has been very little trouble with unnecessary duplication of water mains. There is a duplication of gas mains due to the fact that in the past there were half a dozen more or less companies. They are consolidated now under the Consolidated Gas Company. Years ago when the subway trenches were open the suggestion was made that one large main be substituted for several smaller ones. At that time the gas company was opposed to it. Now they are taking the initiative in the matter and I think there is a fair chance of substituting one large gas main on Eighth Avenue for the half a dozen more or less smaller ones that are there today. When one considers that there must be brought into agreement the officers and bondholders of the Consolidated Gas Co. and its constituent companies as well as the Board of Estimates and Apportionment, the Board of Transportation and the contractors there is a realization that patience and diplomacy are required to accomplish a result that everyone thinks is the right one.

MR. BONIFACE: In the construction of Section 1, Route 38, just as a matter of interest to you, we had to restore some 10-inch main and when we dug it up it was the old Scotch pipe. It was dated 1864. I should like to say that that pipe was just as good when we pulled it up in 1916 as it was apparently when it was put in. Mr. Ridgway showed on one of his plans what they call the preliminary drawings, showing the sub-surface structures. I think the Water Department and in fact all the public utilities departments ought to thank the subway construction division because it, at least, has given us a chance to get the proper plotting of all the sub-surface structures, so that their records were corrected once and for all. We did not find the mains as they were shown originally on the drawings. Now we know where they are.

A. E. HANSEN:³ You showed a very interesting picture of the Eighth Avenue new double-deck subway, if I recollect, with 42- or 48-inch cast iron sewers suspended between the upper and lower levels. The question in my mind is how are we going to run our house sewers from the buildings to those sewers?

² Hydraulic and Sanitary Engineer, New York, N. Y.

ROBERT RIDGWAY:² There are service sewers paralleling the subway. The cast iron sewers referred to by Mr. Hansen are part of the trunk, that is, the three pipes carry the large trunk sewer across the subway. There will be no trouble about the house services as they are connected to the service sewers.

Speaking of the Scotch pipe to which Mr. Boniface referred, in building the original subway about 1902, we had to move a 48-inch main that was on Forty-Second Street, and replace it with a new 48-inch main on Fortieth Street. The old main was in the way of the contractor and as acetylene torches were not available in those days, and as he had difficulty breaking up the pipe with sledges, he hit upon the idea of putting jacks in the main and expanding the pipe until it broke. The horizontal diameter increased, as I remember it, more than 2 inches before any cracks appeared in the pipe.

ALEXANDER POTTER:⁴ I should like to ask Mr. Ridgway, has there been any trouble with those siphons that were built under the subway, and are there many of them?

ROBERT RIDGWAY:² When somebody drops a featherbed down the manhole and it chokes the inlets there is difficulty with the siphon, but ordinarily it works very well. The design takes care of the sanitary flow with a small pipe and the storm flow with two larger ones, usually of cast iron, but sometimes of reinforced concrete. I hear very few complaints about them. There are a dozen or more of them if I remember correctly.

CHARGES FOR PUBLIC FIRE PROTECTION¹

BY R. L. DOBBIN²

This is a subject that has been discussed many times before this Association, and it is probable that it will be discussed many times again. One of the best and most authoritative papers on the subject was presented by Metcalf, Kuichling and Hawley at the Rochester Convention of the American Water Works Association in 1911. There was also another of great value given by John Alvord at the Philadelphia Convention in 1914.

There is also a very interesting chapter in the "Manual of Waterworks Practice" on this subject, which it covers very completely.

However, I feel that the method of calculating the proper amount to be charged for public fire protection can be explained in a little more detail, and there are also other points on which my opinion differs from that of the authors.

The real problem that underlies the question of reasonable return for public fire protection involves a determination of the equitable distribution of the charges for water works service among the various classes of users.

A water works system has usually two sources of revenue, first, from public fire protection service, and, secondly, from domestic service, which latter includes industrial and public uses. It is with the first of these sources that this paper will deal.

The usual method for the determination of reasonable return for public hydrant or fire protection is an annual rental per hydrant. This rental is generally fixed by considering the average rates paid by other cities nearby, and rarely has any logical basis for its calculation.

When the return for public fire service is inadequate, the domestic consumer must make up the deficit. The entire community derives the benefit from adequate fire protection and the cost of it should be charged to the whole ratepaying population.

The individual ratepayer should pay for fire protection in propor-

¹ Presented before the Canadian Section meeting, March 4, 1927.

² Manager, Public Utilities Commission, Peterborough, Ont.

tion to the value of the property protected and not according to the amount of water he uses, or the fixtures in his house. Where the proper charge is made for public fire protection it is collected in the general tax, and each ratepayer pays his share according to his assessment.

An increase in charges to the city for fire protection service does not necessarily mean an increase in the gross earnings in all cases. In a great many cases it will mean a decrease in the domestic rate.

One method of ascertaining the proper charge for fire protection will be outlined in the following paragraphs.

The various items of capital must first be divided between the two main services, and the first to be considered is the distribution system.

DISTRIBUTION SYSTEM

The proper way to make this division is first to make a study of the value of a theoretical system sufficient in capacity for fire alone. Next, make a study of the value of a theoretical system sufficient in capacity for domestic service alone. The sum of these two values will give a value greater than the value of the existing system, and the value of the latter should then be divided between the fire service and domestic service in proportion to the theoretical values calculated in each case.

The value of all service pipes and meters will of course be charged directly to domestic service, and the value of all fire hydrants to fire protection service.

PUMPING EQUIPMENT AND STORAGE

The items of capital should be divided according to the capacity required. The capacity required for fire protection service can best be ascertained by enquiry from the Canadian Fire Underwriters Association.

With regard to capacity required for domestic use, this will depend to a large extent on local conditions. If you have an elevated tank or storage reservoir to supply part of the extra demand at the time of the peak, you will not require such a large capacity in the pumps as the system would which is pumping directly into the mains with no storage.

In the former case, the maximum day's pumpage, plus 50 per cent,

is usually employed. In the latter case the maximum hourly rate of pumpage, plus 50 per cent, should be taken.

Add these two capacities together and find what proportion the capacities for fire protection and domestic service are of the total.

TABLE 1
Division of fixed and operating charges, City of Peterborough

ITEM	TOTAL AMOUNT	DIVISION OF CAPITAL			
		Domestic service		Fire service	
		Per cent	Amount	Per cent	Amount
Mains.....	\$361,417.00	45	\$162,500.00	55	\$198,917.00
Services and meters.....	74,116.00	100	74,116.00	.....	.....
Pumping equipment.....	232,320.00	60	139,391.00	40	92,929.00
Buildings.....	37,478.00	75	28,100.00	25	9,378.00
Office equipment.....	1,609.00	100	1,609.00	.....	.....
Miscellaneous.....	2,878.00	100	2,878.00	.....	.....
Totals.....	\$709,818.00	57½	\$408,594.00	42½	\$301,224.00
ITEM	TOTAL AMOUNT	DIVISION OF OPERATING EXPENSES INCLUDING ALL FIXED CHARGES			
		Domestic service		Fire service	
		Per cent	Amount	Per cent	Amount
Mains.....	\$28,303.00	45	\$12,736.00	55	\$15,567.00
Services and meters.....	8,788.00	100	8,788.00	.....	.....
Pumping equipment.....	24,455.00	60	14,673.00	40	9,782.00
Building.....	2,749.00	75	2,062.00	25	687.00
Billing and collecting.....	4,160.00	100	4,160.00	.....	.....
General supervision.....	6,000.00	57½	3,450.00	42½	2,550.00
Miscellaneous.....	3,460.00	100	3,460.00	.....	.....
Totals.....	\$77,915.00	63	\$49,329.00	37	\$28,586.00

The capital in the pumping equipment and storage will then be divided according to their proportions.

DISTRIBUTION FOR BUILDINGS

In determining the distribution of value with regard to buildings, the proportions should be about as shown in tables 1 and 2.

1. For all buildings not contributory to the pumping of water, 100 per cent shall be charged to domestic service.

2. For all buildings contributory to the pumping of water, 75 per cent shall be charged to domestic service and 25 per cent to fire protection.

TABLE 2

Statement of operating expenses of the Water Works Department for the year 1925, as it affects the charge to the City of Peterborough for fire protection for 1926

Maintenance and operation.....	\$34,422.62	
Fixed charges.....	50,684.60	
Total.....	\$85,107.22	
Less 315 hydrants at \$10.00.....	3,150.00	
	\$81,957.22	
City percentage, 33 1/3.....		\$27,319.07
Plus service charge on hydrants.....		3,150.00
Total charge to city....		\$30,469.07

Since this method was established, the City has paid as follows for fire protection:

YEAR	AMOUNT	NUMBER OF HYDRANTS	AVERAGE PER HYDRANT	AVERAGE PER CAPITA
1921	\$23,062.30	293	\$78.50	\$1.08
1922	25,453.41	297	91.00	1.18
1923	26,815.18	300	89.00	1.24
1924	26,448.23	309	85.50	1.22
1925	28,940.93	311	93.00	1.34
1926	30,469.07	315	97.00	1.41

OPERATING EXPENSES

Now that the above percentages have been determined, we shall proceed to divide the expenses between the two services.

It is, of course, understood that no part of a filtration plant or other purification works is considered in this analysis. The capital charges and operation and maintenance expenses for this portion of a water works system should be charged directly to domestic service.

Operation and maintenance of mains should be divided on the percentages found for the distribution system, as also the fixed charges, such as interest and sinking fund and depreciation, etc., the latter, however, pertaining only to the distribution system.

Operation and maintenance of services and meters, together with the fixed charges on these, should all be charged to the domestic service.

The operation and maintenance of pumping equipment, together with the fixed charges, should be divided according to the percentage found for the capital charges, and similarly with the upkeep of buildings.

The cost of billing and collecting should be all charged to domestic service.

General expense and supervision should be divided according to the proportion of the total capital in each case.

The above is a brief outline of the procedure necessary to calculate the proportion of the annual cost chargeable to domestic service and fire protection.

To illustrate how it works out, I will give the values found for the city of Peterborough, made in 1921, in table 1.

Metcalf, Kuichling and Hawley deduced the following formula, in which y is the percentage of the total capital cost of a water works system which should be charged to fire protection, and x is the population in thousands:

$$y = \frac{147}{x^{0.11}} - 12.1$$

This works out in Peterborough in 1921 as about 45 per cent, which figure agrees very well with that found by investigation.

The statement is also made in that paper, that the cost of the portion of the water works plant involved by fire protection service, probably constituted from 60 to 80 per cent of the entire cost of the physical property in the case of communities having less than 5,000 population, 20 to 30 per cent in communities of 100,000 population, and perhaps 10 to 20 per cent in the case of our largest cities.

This statement is borne out by subsequent investigations as noted in the "Manual."

CHARGING FOR FIRE PROTECTION

The Manual gives three general methods of determining the annual charge for fire protection service, as follows:

1. Hydrant rental.
2. Charge per mile of pipe, with an allowance per hydrant for maintenance.
3. Charge per inch-foot of pipe distribution system, with allowance per hydrant.

To these I would like to add a "percentage of annual cost" method which I will explain later.

The first of these methods is the oldest and, as I said at the opening of this paper, is not logical.

For one thing the value of fire protection is in no way proportional the number of hydrants and it also tends to keep down the number installed.

The second method is better than the first, because it takes into consideration, to some extent, the size of the system, and would permit of increase, proportionately as the system expanded. But it does not take into consideration the sizes of the pipes.

This is where the third method is superior. The number of "inch-foot" units is determined by multiplying the linear feet of pipe of each diameter by the diameter in inches.

The annual charge per hydrant is based upon the average annual cost of operating, maintaining and repairing the hydrants.

Many charges of this latter type have been established in the United States, varying from \$2.25 to 76 cents per inch-foot, and averaging about \$1.23.

On this basis of charge, Peterborough would be rated at \$1.31 per inch-foot for 1921.

The inch-foot system has the advantage that the total charge is in proportion to the pipe capacity as well as to the number of hydrants. But the true cost also depends on other features of the plant of which this system of charging does not take cognizance. Then, too, the city might object to laying the larger sized mains as this would directly increase their cost. The capacity and cost of a main, in addition, do not vary directly with the diameter.

The fourth method, which is not included in the "Manual's" list, may be called the "Percentage of Annual Cost" and is the one adopted in Peterborough.

Based on the results as shown in table 1, we decided to charge one-third of the annual expense of running the water works system, exclusive of filtration, to fire protection, and have so billed the city each year.

We, however, did not wish to base the charge entirely as above, but thought it wise to make it in the following form:

A certain small part of the cost of fire protection is proportional to the number of hydrants, that is, the investment in the hydrant itself and its maintenance. Our system of bookkeeping did not show the

investment in the hydrants as separate from the mains, but we estimated this to be, on an average, \$100 each. The fixed charges on this sum amount to about \$7.50, and we estimated that maintenance would average \$2.50, therefore we put the total annual cost per hydrant at \$10.

TABLE 3
Amounts paid for fire protection in 1926 by cities in Canada

CITY	POPULATION	TOTAL COST OF UPKEEP	NUMBER OF HYDRANTS	FIRE PROTECTION CHARGES			
				Total amount collected	Rental per hydrant	Per cent total upkeep	Per capita
Toronto.....	525,000	*	7,190	964,818		36.6	\$1.84
Montreal.....	568,000	\$2,284,329	3,401	None	None	None	
Winnipeg.....	197,000	997,911	2,757	76,470	30	7.7	0.39
Ottawa.....	127,100	514,529	1,565	None	None	None	
Quebec.....	125,000	425,000	1,200	None	None	None	
Hamilton.....	123,395	542,938	2,262	20,000		3.7	0.16
London.....	67,000	269,093	1,066	19,188	18	7.1	0.29
Edmonton.....	65,000	487,264	910	40,507	45	8.3	0.62
Regina.....	40,000	246,152	576	43,037	75	17.5	1.08
Brantford.....	27,739	*	424	23,320	55	*	0.84
Walkerville.....	27,000	*	440	15,464	65/35	*	0.57
St. Catherines.....	26,000	65,505	474	9,480	20	14.4	0.37
Kitchener.....	25,856	100,304	370	13,658	35	13.6	0.53
Peterborough.....	21,519	85,107	315	30,469		33.3	1.41
Niagara Falls.....	20,000	76,480	297	8,900	30	11.6	0.45
Stratford.....	19,000	59,855	271	8,979	40/30	15.0	0.47
St. Thomas.....	17,000	78,043	218	12,750	60	16.3	0.75
Chatham.....	15,000	51,000	240	9,600	40	18.8	0.64
Woodstock.....	10,000	38,961	185	6,475	35	16.6	0.65
Orillia.....	8,000	43,266	143	5,362	37½	12.4	0.68
New Toronto.....	5,023	75,000	98	2,450	25	3.3	0.49

* Not given.

So we charge the city a straight \$10 per hydrant, subtract this amount from the total cost of operating, and charge the city one-third of the balance.

For illustration, in table 2 the details of our bill to the city for 1926 are given. I might say here that the charge for a certain year is based on the expenses for the preceding year.

By this method, the total charge is increased in proportion to the

growth of the system. If a large main is laid, the annual cost will be increased more than if a smaller one were laid, and consequently the charge for fire protection is increased. Also, if other parts of the system are increased, a part of the annual cost goes into the fire protection charge.

In order to ascertain the situation in Ontario, with regard to this subject, a questionnaire was sent out to about twenty municipalities and the information received was listed in table 3.

This table shows that there is a wide variation in the amounts charged for fire protection. Two cities in the list, Toronto and Peterborough, are on a percentage basis, the former charging 36.6 per cent of the annual expense, and the latter $33\frac{1}{3}$ per cent.

Three of the cities, Montreal, Quebec and Ottawa, charge nothing at all.

Leaving out those cities which charge on a percentage basis and also those in which nothing is charged, the weighted averages are as follows:

Hydrant rental.....	\$29.40
Per cent of annual expense.....	8.5
Per capita, dollars.....	0.46

It is apparent from these figures, that nearly all the cities listed in table 3 are not charging enough for public fire protection.

DISCUSSION

E. V. BUCHANAN: I would like to compliment Mr. Dobbin on his excellent paper on "Fire Protection Charges." No doubt from a purely theoretical standpoint, Mr. Dobbin's method of obtaining the proportion for the cost of domestic service and fire protection is correct, but I am inclined to think that, where city councils have to be dealt with, the argument is somewhat unconvincing.

There is no doubt that there are municipalities whose system is no more adequate than necessary for domestic requirements and yet, because of local conditions, may be quite suitable for fire-protection purposes.

In recent years fire departments have gone through a period of rapid changes. The horse-drawn hose reels have given place to motor trucks and high-powered pumping units. Also water is not the only weapon of the fire department, but extinguishers and chemicals play an important part, so that the function of the water works department is not so great as formerly.

I think that it is generally accepted that the first duty of the water works department is that of supplying water for domestic, sanitary and industrial uses; and secondly, for fire protection. If that is so, then the municipality as a customer for fire protection service may be looked upon as one to whom a by-product, so to speak, may be sold.

If we look at the problem from this point of view, the division of costs will be entirely different. First, all costs that are specifically incurred for fire protection could be computed. These might be fire hydrants, fire pumps in pumping stations, and additional reservoirs necessary under the Fire Underwriters' regulations. Then there would be the cost of the increased size of mains necessary because of the fire-protection service. The extra cost of maintenance, operation and overhead could be arrived at, and so a total cost would be obtained which would be much less than that derived by Mr. Dobbin by laying out two hypothetical systems.

Following out a method of this kind, I have roughly arrived at a figure of 20 per cent. Although this is much lower than the figure worked out by Mr. Dobbin, it is still greatly in excess of the charges made by Canadian cities, with the exception of Toronto.

When we, as water works men, are making analyses such as these to see if we are getting our "pound of flesh," it may be well to consider the question which has been raised time and again, namely, "Should publicly-owned utilities pay taxes on the same basis as private corporations?" It has never seemed to me that there is any logical argument against such a proceeding, and as taxes charged by the city against the water works department would have to be distributed over the consumers by increase of the water rates, and on the other hand as fire-protection charges made to the city by the water works department have to be divided among the taxpayers, these two charges could be placed against one another on an even basis for cancellation.

I admit, however, that the taxes on a water works system should not amount to much more than 5 to 10 per cent of the gross expenditures.

The basis of the paper is the distinction which is made between the taxpayer and the water consumer. Let us consider for a moment the responsibility of the water consumer to the taxpayer. The water consumer demands of the taxpayer—represented by the corporation—that an adequate supply of water be furnished. The taxpayer says that he has not the money necessary to do what is asked without borrowing it, and he is told by the water consumer to borrow it then,

and so Mr. Taxpayer agrees, but he is entitled to some consideration for mortgaging his property for the benefit of the water consumer, and so should obtain a service to protect his mortgaged property at a very minimum of cost.

It is desirable in our modern municipalities to keep the tax rate as low as possible, and so avoid keeping people away through fear of a high tax rate. Therefore, we should spread out as much as possible, and over as many objects as possible, the charges required to provide the modern conveniences and necessities; so let the water consumer pay all the items that can be logically charged against him. Might I venture to suggest that the raising of a fire-protection charge may be prompted in some cases by a desire to dodge the unpleasantness of raising the water rates to the water consumers?

The point which I wish to make is that, as a matter of good business policy, the water works department should demand not more than about 15 to 20 per cent of the total cost as a fire-protection charge.

With regard to the method of assessing the fire protection charge, I am in favor of some combination system such as charge No. 3 mentioned by Mr. Dobbin, namely, "charge per inch-foot of pipe distribution system," with an allowance for maintenance of each hydrant. I do not believe that there can be much objection to this method, as the necessary number of hydrants and size of mains can be easily determined, and should not be objected to by any reasonable council on the plea of economy. If the method of assessing as recommended by Mr. Dobbin is approved, then I believe that the actual percentage of cost should be worked out each year to determine the bill. The fact that the figure arrived at in 1921 in Peterboro was $33\frac{1}{3}$ per cent does not mean that the percentage for 1927 will be $33\frac{1}{3}$ per cent.

After having worked out the cost for fire protection by some predetermined method, the allocation of this cost could be made, let us say, for method No. 3, namely, "per inch-foot of distribution system," and per hydrant, and the unit charges so derived used for a period of years. The total charges would grow with the system in a more equitable proportion than "the percentage of annual cost method."

The tables bring out very strikingly that the charges for fire protection are not adequate.

Mr. Dobbin has rendered a valuable service to water works men in presenting this excellent paper, which is well worth a close study not only by water commissioners but also members of city councils.

G. F. LEWIS: The discussion of Mr. Dobbin's paper on "Fire Protection Charges" opens up so many channels that it is difficult to dispose of it in a few words.

The lack of uniformity—or basis for such charges—is summed up in Mr. Dobbin's own words when he says, "This rental is generally fixed by considering the average rates paid by other cities nearby, and rarely has any logical basis for its calculation."

I cannot agree with Mr. Dobbin when he says that the individual ratepayer should pay in proportion to the value of the property, and not according to the amount of water he uses, or the fixtures in his house.

To my mind there is neither equity nor justice in this plan. The carrying out of such a policy would penalize the manufacturer, who uses practically no water in making his finished product, for the benefit of the manufacturer whose finished product depends almost entirely on the treatment and use of enormous quantities of water before it can be marketed.

Mr. Dobbin further argues that an increase in charges for fire protection service will mean a decrease in the domestic rate. Again we have an incongruous condition presented, for statistics show that two out of every three fires occur in dwellings. One fire, however, in a large manufacturing plant may use up as much water as all the fires in dwellings in the town do in an entire year; again throwing any set formula out of gear.

The strongest argument against the excessive charges made for municipal fire protection is the fact that in laying out a water works system, adequate fire protection is the last thing considered.

It has been the practice of municipal officials to provide water primarily for domestic service on a revenue-producing basis, secondly for sanitary purposes, thirdly for industrial use, fourthly for public service, and fifth and lastly for fire fighting purposes. Notwithstanding the installation of a large percentage of 4-inch mains—which are not standard for fire-fighting purposes—engineers are aware that large quantities of water must be readily available for the purpose of extinguishing extensive fires. With fire protection first, all the other requirements would be amply supplied.

I cannot see the object "in making a study of the value of a theoretical system sufficient in capacity for fire alone," if that system be not actually installed. Nor is the suggestion practical of asking the C. F. U. A. for "the capacity required for fire-protection service" for

the purpose of charging the full amount of such service as fire protection, as the great majority of municipalities are deficient in their pumpage or reservoir capacity.

I do not agree with the statement that "the value of fire protection is in no way proportional to the number of hydrants," for the number of hydrants is most certainly proportional to fire protection.

The tables compiled by Mr. Dobbin are very interesting, but in addition to the fire protection charges, which run from 16 cents per capita in Hamilton to \$1.41 per capita in Peterboro and \$1.84 per capita in Toronto, it would have been very illuminating to know the water rates charged to consumers in the 21 municipalities under review.

Naturally in cities like Toronto and Peterboro, where charges per hydrant amount to \$134.19 and \$96.72 respectively, the water rates charged to consumers should be correspondingly low, and, of course, the deficit or difference is included in the taxpayers' bills under the cover of fire protection.

Independent or privately-owned water works systems do not find it necessary to make any such high charges for fire protection. If they did, the citizens would soon rise in protest.

Three cities—Montreal, Ottawa and Quebec—absorb the cost of fire protection in the rates charged to consumers. London charges at the rate of \$18 per hydrant per year for fire protection, and makes money on its water works system.

I know a town where the annual charge for water for fire protection purposes exceeds the amount of their annual fire losses. In that case, water would appear to be somewhat of a luxury.

Fundamentally the entire question is really a matter of bookkeeping, for the citizens must pay the bill.

The idea evidently is in some cases to charge as much as possible to the fire department, to be liquidated by the citizens in their tax bills, so that water rates may appear to be kept down.

I think that the members of the American Water Works Association could easily work out a uniform standard of distributing costs which would be much more satisfactory than the systems now in vogue.

N. R. WILSON: I am sure we are all in agreement that this is a very excellent paper, and that Mr. Dobbin has evidently made an exhaustive study of the subject. I agree that you have to get a theoretical

basis to start with in regard to the distribution system. You do not have to use the same class of pipe for a domestic service that you would have to use for a fire service.

You have to have pumps for the domestic service, but 40-lb. pressure would be ample. But for the fire service they have to run up to 110 or 120-lb. pressure. Therefore, unless you have some theoretical basis to act on, you cannot begin anywhere.

I cannot agree with Mr. Dobbin that no part of the filtration plant should be charged to fire protection. Where you have filtration, all the water that is used for fire purposes has to pass through the filtration beds. You have to increase the capacity of the filtration plant in order to cover fire service.

T. H. HOOPER: I cannot help but think that Mr. Dobbin's paper is more or less based on the town of Peterborough. Naturally he has worked it up from his day-to-day work in his own town. Conditions in this Dominion vary so much that it would be extremely hard to arrive at a rule that would apply to all places. In Winnipeg we figure that \$30 per year is a fair charge for a hydrant. See what we give for that: We have to maintain these hydrants; every time that a hydrant is used during the winter months it has to be repacked, and the work has to be done as quickly as possible, because the fire might break out a second time. We put on as many as twenty and thirty inspectors, and in the down-town district we inspect the hydrants frequently, and in other parts of the town once a month. Once a hydrant is packed in the fall, I think the best thing is to leave it alone unless there is a leak. Constant inspection often sets up small leaks. We have a high-pressure system in Winnipeg, and we can pump up to as high as 300-pound pressure. That system is confined to the wholesale district and that district is charged with the maintenance, and the principal and interest is charged to the city as a whole.

I hope that we will have as interesting a paper on this subject next year, and that it will be put on early, so that we can have more time to digest it.

WM. GORE: Mr. Dobbin has adopted a scientific method for calculating the cost of fire service. There appear to be three different scientific methods of the type he has adopted: One is to assume that the whole city is laid out for domestic water works purposes, and the esti-

mate the cost of adding on the fire service; that would give a certain figure. Another method is to assume that the water works is laid out primarily for fire service, and then estimate the cost of the domestic service in addition to that. The third method is to estimate it as a partnership affair, and I believe that is what Mr. Dobbin has done.

W. C. MILLER: In discussing Mr. Dobbin's paper I should first point out that it is a type of paper that should be presented at a convention of municipal officials who are not exclusively interested in water works.

Mr. Dobbin's conclusions are marshalled very plainly and effectively, and there would be no difficulty in maintaining them in the face of any possible discussion presented from the point of view of the official who represents that phase of the public entity concerned with paying for fire protection by a mill rate on his assessment.

The question of charges for public fire protection is a live one, for most plant managers who are not in the fortunate position of Mr. Dobbin, whose plant receives an equitable revenue from such service. The writer finds that among those plant managers with whom he has discussed the question personally, the rate for public fire protection is arrived at usually by means of a compromise between the Water Board and the City Council, on the assumption that the City Council, representing the department called upon to pay these charges, has as much to say in deciding what this rate should be as has the Water Board, and that in the final analysis the City Council must be agreeable to the rate struck before it can be collected from them. The result of this attitude is quite plainly seen in Mr. Dobbin's table 3, where the percentage of total revenue received from fire protection is practically only a nominal one in many cases.

I should like to ask Mr. Dobbin whether, in arranging for this charge in Peterborough, it was the stand of his board that the final decision in the matter rested with his board or with the council; and if there was any question as to who had jurisdiction in the matter, what statute authority, if any, justified the final action.

In St. Thomas we have made a separation of the present capital charges of the various parts of our plant, having to do with fire protection, as follows:

	TOTAL VALUE	PER CENT TO FIRE PROTECTION	TOTAL VALUE FOR FIRE PROTECTION
Mains.....	\$373,695	65.5	\$245,000
Fire hydrants.....	14,338	100.0	14,338
Pumps.....	45,000	81.6	36,750
Pump house.....	17,250	25.0	4,300
Elevated water tower.....	222,057	0	
Services.....			
Meters.....			
Filtration plant.....			
	\$672,340	44.7	\$300,388

Including suburban consumers, this plant supplies about 18,000 people. Metcalf, Kuichling and Hawley's formula for a population of 18,000 gives the percentage as 47.9 per cent.

In these figures construction for storage is not included. It would obviously be difficult to strike a comparable percentage if such works were included, since, to take an extreme case like that of St. Thomas, approximately 25 per cent of the total capitalization is involved in works for the collection of water from a small watershed, while another plant might have a supply works consisting of wells, or, if situated close to a body of water, simply an intake, the cost of which would be a very small proportion of the total capitalization.

These figures are submitted simply as evidence of another plant that has been analyzed, and the proportions of which, as segregated between fire protection and domestic service, follow substantially Metcalf, Kuichling and Hawley's formula, as quoted by Mr. Dobbin.

In many plants the practice is followed of paying as they go for certain normal annual capital expenditures, covering such things as meters, services and small main extensions, which expenditures provide for the normal expansion of the business, any abnormal extension being taken care of by the issue of debentures.

In a case of this kind, covering only these normal extensions, would Mr. Dobbin use the cost of these extensions as affecting the "percentage of annual cost" rate, or would he apply the previously calculated percentage to the cost of these normal extensions and include this in his bill for fire protection, with the correct proportion of the cost of operation and maintenance, based on his revenue and expense sheet?

For the purpose of bringing Mr. Dobbin's table 3 up to date, I would

point out that, in the case of St. Thomas, since this table was compiled, the hydrant rental charge has been increased to \$80, thus making the total amount collected \$17,440 per annum, this being 22.3 per cent of the total upkeep, or \$1.03 per capita.

I had hoped that Mr. Dobbin might have touched on the question of private fire-protection charges, which topic is coming to the fore more and more each year with the promotion of automatic-sprinkler systems.

W. L. McFAUL: I have been greatly interested in Mr. Dobbin's paper and I am sure that he has given us a great deal of matter for study. The conclusions that he has arrived at are no doubt quite in accord with his system. I must say that the conditions of financing water works where the commission is independent of the city council are slightly different from a financial undertaking where the municipal system is directly under the control of the council. Broadly speaking, in a city such as Hamilton, I would say that 10 per cent of the gross revenue of the water works would be ample to charge for fire purposes. That is certainly more than we get at the present time. It would be an outside figure, taking into account every consideration.

A. U. SANDERSON: Mr. Dobbin uses the same system that we use in Toronto, and as a representative from the only other city using the same system that he does, I would like to say a few words. Mr. Gore's analysis of the scientific lines on which the subject should be approached seems to put the situation very clearly. If, like Mr. Lewis, you are representing the fire interests, and look at the matter from the point of view of the fire protection that the taxpayer receives because the water works was there first, then you could make out a very good case. Mr. Lewis and Mr. Buchanan did make out a very good case. It appears to me that both these gentlemen were influenced in their attitude of mind towards the question. I am sure that Mr. Buchanan could make out a very good case for his high service charge in London. We could argue this case all night, pro and con, but if it is argued from a scientific point of view I think that it would be very hard to make a case against Mr. Dobbin's paper, which is really a scientific system of charging for fire protection.

R. L. DOBBIN: The discussion has been very interesting. Most of the gentlemen said very nice things about the paper. The greatest

compliment, I think, is the discussion that took place. This paper was designed in the first place to show what my opinion was as to the proper method of designing a charge for fire protection, but most of all it was designed to bring out some discussion, and I think that you will admit that it had that effect.

I left a number of loop-holes, which Mr. Lewis promptly found, as did also some of the other speakers. I have not prepared any direct answer to them. In London apparently they are short \$35,000 which they should get from the city. That is only 50 cents per capita and would not make any difference in the London taxes, which I understand are high.

Mr. Buchanan brought out the point that we should adjust these rates each year. As a matter of fact, we should adjust them every time that we put in a new main. With us the adjustment is made every ten years. I made an analysis of our system, and for last year there was very little difference in the charge; it was 37 per cent in the first analysis in 1921, and last year it was just about the same.

The question brought up by Mr. Miller was as to what authority we have to charge these rates. At the time that we put this rate in operation, Mr. Gordon, a prominent lawyer in Peterboro, attended the meeting, and had with him two or three law books, and he looked at us, like a judge, while we were making our statement, and then he said, "We do not have to pay it." We replied that the public utility commission was given power to make rates, and we considered the fire-protection charge as a rate. He looked at his law books and said, "I guess you are right," and the charge stood.

We passed the by-law for ten years, and we consider that we scored a considerable victory, for Mr. Gordon was there for the purpose of telling us where to get off. You will find the public utilities act will allow you to make a proper rate. In Toronto the water works is run by the city council, and they must have some way of inducing the city council to charge the proper amount for public fire protection.

G. F. LEWIS: Are you building up a surplus by these charges?

R. L. DOBBIN: Under our act we are allowed to keep a certain amount as a surplus. That surplus has now come up to the point which we cannot keep any more, and we are turning it back to the city.

C. J. PRATT: Did you cut down your ordinary water rates when you adopted these excessive hydrant charges?

R. L. DOBBIN: The answer to that is that we are putting in a new filter plant.

E. V. BUCHANAN: I am afraid that my remarks were rather rambling. Mr. Gore claims that this sytem has some scientific basis. Assuming that the water works sytem was put in for domestic purposes, it would be proper to calculate the extra amount necessary to provide fire protection. I do think that water consumers owe something to the taxpayers who provided the money for building the water works.

A. U. SANDERSON: The city of London provided the money, but the water works provides the interest on the debentures and retires them when due.

E. V. BUCHANAN: The rural customer on the "Hydro" makes the statement that the city does not pay; that the province of Ontario puts up the money and that the province of Ontario owns the Hydro system; and he claims that the man in the rural community is entitled to some consideration on that account. I do not see why that same principle is not justified in this case. No water works that I know of is paying taxes, and I do not believe that any logical argument can be advanced as to why a water works system should not pay taxes.

T. H. HOOPER: We pay taxes in the city of Winnipeg.

A. U. SANDERSON: When the Dominion Government guaranteed the bonds of the railway companies, both the C.N.R. and the C.P.R., they did not become the owners of the railways and finally they had to buy one of them.

T. R. LOGAN: Our water works system pays taxes the same as every other taxpayer, and we make everybody pay for the water they use.

T. HODKINSON: Mr. Dobbin said that he had 315 hydrants; and how many miles of mains?

R. L. DOBBIN: Fifty. The city council have control of placing the hydrants, and that is the reason that we make the ten-dollar charge, so that if they want an abnormal number of hydrants, they will have to pay for them.

THE CHAIRMAN: One point has been overlooked in this discussion: The mains are not extended to all parts of the municipalities, and these sections would not have any fire protection and, yet with the charge that Mr. Dobbin is making, the taxpayer would be paying for fire protection that he was not getting.

R. L. DOBBIN: I want to express my thanks to those members of the association who answered my questionnaire and gave me the information that I required. I would like these members to go back with my paper and try to figure out what the percentage should be. Then, with your permission, I would like to collect that information a year from now, and make out another table and show the results. Probably we might have some discussion on this subject at our next meeting. It might be possible to have a debate on the subject.

C. R. COLE: I represent a municipality of 50,000 population. We have 1,600 hydrants. The majority of our mains are put in under the local improvement plant. We have nothing less than 16-inch mains, and we install a hydrant every 300 feet, and the people on the street pay for them.

N. R. WILSON: Brantford pays taxes on the pumping station and all buildings.

W. C. SMITH: So much per hydrant as the basis of the charge for fire protection is rather peculiar. Water works constitute 35 per cent of the total credit allowed municipalities for fire protection. It is allowed equal credit with the fire department. That shows that they put the water works department on as important a footing as the fire department. If the fire department costs \$25,000 a year, should not the city pay a similar amount for the other branch of protection, the water works?

Speaking on annual charges for hydrants, I think it has a very strong tendency to make the city conserve on the number of hydrants. Would it not be better to select a certain proportion of the total of

fixed charges and operating costs for each year, which for a small community of 10,000 people would be a much higher ratio than for a city of 50,000? I think that, in Mr. Buchanan's city of 65,000 people, it would be a much smaller proportion of the whole than it would be in Mr. Dobbin's municipality. As a matter of fact, I think that the basis of charge should be struck for various types of municipalities, and should be more upon the number of mains installed in the municipality.

In my city we have analyzed this thing carefully in an effort to get more money from the city. We are now getting, on behalf of fire protection, $6\frac{1}{2}$ per cent of our total fixed and operating charges, which I contend is less than one-quarter of what we should get for that service. It is difficult to have any change made, but we have given the city notice that on the first of January, 1928, the rate of hydrant rental will be increased 25 per cent, making the rate \$60. Tenants occupy 45 per cent of the buildings in the city, and they are paying for the fire protection. We have a bank building, say worth \$100,000, where they use water equivalent to a small householder. The bank pays nothing for fire protection, unless they pay for it through the medium of the tax rate. The taxpayers are now paying a greater ratio, but not a sufficient ratio, because the small householder pays a much higher rate on the small quantity of water used.

EXPERIMENTS IN THE HYDRAULICS OF FILTER UNDERDRAINS

BY N. MALISHEWSKY¹

The lateral underdrains of rapid sand filters at present generally consist of perforated pipes or tubes, the perforations being of the same diameter equally spaced. When washing a filter the underdrains must supply water as uniformly as possible. For this purpose it is necessary that the head in the perforated laterals should be equal over their entire length. Due to the movement of water through the lateral, head is lost by friction. Therefore, it would seem that the head at the end of a lateral would be less than at its entrance, but by the gradual reduction of velocity of flow in a perforated lateral it is assumed that the velocity-head $\frac{V^2}{2g}$ will increase and, due to this, the head toward the end must tend to increase.

In order to explain the result of the apparent reciprocal action of these two opposite tendencies, the author together with Professor G. T. Proskura undertook the experiments described later, in the laboratory of the Technological Institute of Kharkow.

THE EXPERIMENTAL DETERMINATION OF HEAD IN LATERALS 2 INCHES IN DIAMETER

Figure 1 indicates the arrangement of piping used during the experiments. *A - B* is a lateral 2-inches in diameter with 40 orifices, each 5.5 mm. in diameter, 20 orifices are on each side, equally spaced between points *C* and *B*, and the tube between *A* and *C* is unperforated. The distances between the points *A*, *B*, *C*, and *D* are shown on the figure. The end of the lateral at *B* is closed. Water is forced through it by a pump, passing from *A* to *C* and then out through the orifices on either side of the lateral between the points *C* and *B*.

¹ Professor of Hydraulics, Technological Institute of Kharkow, Russia.

FIRST EXPERIMENT

In the first set of experiments, October 21, 1926, a quantity of water equal to 3.333 liters per second was tried. Five observations were made and the average observed water levels, recorded by piezo-meter tubes, are shown on figure 1, the water levels being measured from the top of the 2-inch lateral. The loss of head through the unperforated part of the lateral having a length of 2 meters is 173

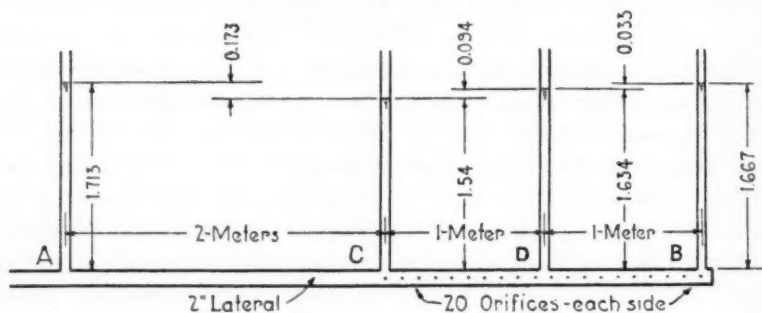


FIG. 1

TABLE 1

	OBSERVED HEAD	THEORETI- CAL VELO- CITY-HEAD CORRE- SPONDING TO LOST VELOCITY	THEORETI- CAL LOSS OF HEAD BY FRICTION	OBSERVED LOSS OF HEAD BY FRICTION
	meters	meters	meters	meters
Difference of heads between C and D..	0.094	0.1025	0.0516	0.0085
Difference of heads between D and B..	0.033	0.0342	0.0061	0.0012

mm. With a discharge equivalent to 3.333 liters per second the velocity in the 2-inch lateral is $\frac{3.333}{0.2027}$, or $V_1 = 1.64$ meters per second.

At point D the theoretical velocity will be equivalent to one-half of the above or $V_2 = 0.82$ meter per second. The velocity-head at point C is $\frac{V_1^2}{2g} = 0.1367$ meter, and at point D it is $\frac{V_2^2}{2g} = 0.0342$ meter. The difference of velocity-heads between the points C and D is $0.1367 - 0.0342 = 0.1025$ meter. The observed heads show the

increase of pressure towards the end of the lateral to be almost equivalent to the lost velocity-head caused by the decrease of velocity from *C* to *B*. The friction losses in the perforated part of the lateral have very little influence upon the height of head. These facts are set forth in table 1.

The losses of head were calculated by the formula:

$$dh = \frac{K(Q + qx) dx}{d^5}; \quad h = K \frac{l}{d^5} (Q_1 + 0.55 Q_2)^2$$

The coefficient *K* is determined from the experiment of the loss of head in the unperforated part of the lateral between points *A* and *C* by means of the equation:

$$0.173 = K \frac{2(0.00333)^2}{(0.0508)^5}; \quad K = 0.0027$$

The observed losses of head are 5 to 6 times less than the theoretical and this is the surprising phase of this phenomenon.

SECOND EXPERIMENT

On October 23, 1926, the experiment was repeated with *Q* = 3.5 liters per second and it was ascertained that between *A* and *C* there was a loss of head equivalent to 180 mm., between *C* and *D* there was an increase of head equivalent to 100 mm. and between *D* and *B*, 30 mm. The results obtained were almost identical with the foregoing, except the last value, 30 mm., which is somewhat smaller, due to the difficulty in obtaining measurements caused by fluctuations of the water level in the piezometer tube.

The area of one orifice 5.5 mm. in diameter is 23.75 sq. mm. The area of the 40 orifices is 950 sq. mm. The sectional area of the 2-inch diameter lateral is 20.268 sq. cm. The velocity of flow *V* in the lateral is 1.64 meters per second.

The velocity in orifices is: $1.64 \times \frac{20.26}{9.5} = 3.5$ meters per second. Using the coefficient of throttling a water jet as 0.62 the effective velocity becomes $\frac{3.5}{0.62} = 5.63$ meters per second. The corresponding velocity-head $\frac{V^2}{2g} = \frac{31.6}{2 \times 9.81} = 1.61$ meters, which corresponds closely to the observed height of head.

THIRD EXPERIMENT

Another experiment was tried on October 23, 1926, with a smaller discharge, or $Q = 2.52$ liters per second. The observed heights of head are shown in figure 2, and the comparison between these and the theoretical are shown in table 2.

The velocity in the unperforated part of the lateral between A

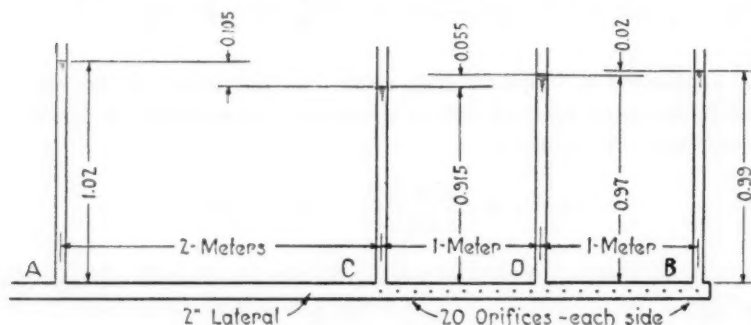


FIG. 2

TABLE 2

	OBSERVED HEAD	THEORETI- CAL VELOC- ITY-HEAD CORRE- SPONDING TO LOST VELOCITY	THEORETI- CAL LOSS OF HEAD BY FRICTION	OBSERVED LOSS OF HEAD BY FRICTION
	meters	meters	meters	meters
Difference of heads between C and D..	0.055	0.0594	0.0309	0.0044
Difference of heads between D and B..	0.020	0.019	0.0041	0.001

and C is $V_1 = \frac{2.52}{0.2027} = 1.243$ meters per second. At point D it is one-half of the above, or $V_2 = 0.621$. The velocity-head at point C is $\frac{V_1^2}{2g} = \frac{1.54}{2 \times 9.81} = 0.0784$ meter, and at point D it is $\frac{V_2^2}{2g} = 0.019$ meter, the difference being $0.0784 - 0.019 = 0.0594$ meter.

The discharge velocity through the orifices with $D = 5.5$ mm. is $V = 1.243 \times \frac{20.26}{9.5} = 2.64$ meters per second. The effective velocity

$$\text{is } \frac{2.64}{0.62} = 4.27 \text{ meters per second. The corresponding velocity-head}$$

$$\text{is } \frac{V^2}{2g} = \frac{18.2}{2 \times 9.81} = 0.93 \text{ meter.}$$

FOURTH EXPERIMENT

Another experiment was made on November 5, 1926, using the drainage system of the rapid sand filter of the Malinowskaia Station of the Kharkow Water Supply Board. The size of filter is 5.3×4.3 meters = 22.8 square meters. In the center of the filter, running lengthwise, is a 100 mm. diameter manifold with 22 branches or laterals, each $1\frac{1}{2}$ inches in diameter, 11 to each side. During the experiment every other lateral on one side was closed, thereby leaving 12 in operation; 6 of these were on each side and the distance between the active ones was approximately 1 meter. Water was supplied through one end of the manifold, the other end being closed. The discharge was 60.5 liters per second or equivalent to a velocity at the beginning of the manifold of 7.66 meters per second. The velocity-

head $\frac{V^2}{2g} = \frac{58.5}{2 \times 9.81} = 3.0$ meters. The observed heads, in meters, on the manifold were as follows:

At the beginning.....	2.12
1.85-meters from the beginning.....	3.44
At the end, or 5.1-meters from the beginning.....	4.14

The head at the end of the manifold appeared to be 2.02 meters higher than at the beginning. The friction loss was $3 - 2.02 = 1$ meter. The loss of head as calculated by Gorbachew's formula is $\frac{5.5}{3} = 1.83$ meters. The loss is calculated on the basis of old tubes, whereas we had a new-asphalted cross-connection 4 inches by $1\frac{1}{2}$ inches, but there were 10 bell and spigot joints in the distance of 5-meters.

CONCLUSIONS

1. The method of calculating the loss of head in wash water underdrains is not mathematically correct.
2. In the cases described above, the velocity-head shows a greater influence on distribution of water than the friction loss of head.

3. It may be possible to obtain an equal head along the entire lateral, by means of an artificial increase in the loss of head in the lateral in such a manner as to make it equal to the velocity-head.

To solve the last problem the laboratory of the Technological Institute of Kharkow is preparing to conduct some experiments. It seems that the most convenient type of filter for this purpose will be one having wooden laterals of rectangular section for underdrains.

A GENERAL RULE FOR MAKING EXTENSIONS

By R. E. DUFFY¹

Many persons engaged in, or whose duty it is to pass upon, the work of extending lines or mains to furnish service, such as electric, water or gas, to customers in new locations realize the wide differences in the rules by which various utilities will extend their distribution systems. The extension rule, as it is commonly called, of some utilities requires the customer to finance the extension by depositing with the utility the estimated cost of the extension less a fixed amount borne by the utility. The amount deposited by the customer may be a large or small portion of the entire cost depending upon the estimated cost. The utility agrees to rebate to the customer a fixed sum for each new customer served from the extension during the first three to five years following the extension, the total refund to be no greater than the amount deposited by the customer. Other utilities agree to rebate a certain per cent of the customer's bill during the first few years of the extension. Some have rules requiring the customer to pay for the entire cost of the extension and make no refund.

The cost of the extension under the above rules and many other similar ones is set up as fixed capital owned by the utility. The rates charged are generally those charged the other customers of the same class, but to whom the service has been furnished without a deposit or extension charge, having come within the allowable cost of extension for a new customer. If the distribution system of the utility is growing and extending rapidly so the extensions are absorbed into the general distribution system before replacement must be made no special note ordinarily is made of the replacement. The increased load may also have required replacement before it is required by depreciation. But the extending of electric lines to serve rural or farming customers is now bringing to the attention of some of the utilities the weakness of some of the extension rules. The lines were built sufficiently long ago to need replacement now.

¹ Chief, Water, Gas and Electric Department, Public Service Commission, Jefferson City, Mo.

The original customer was allowed to believe that, by paying for the initial cost of the line, service could be secured indefinitely at the same rate for which it was furnished in the adjoining city or for about the same rate, the minimum monthly charge probably being greater. The company now finds it cannot afford to rebuild the extension under the rates charged. The customer, if required to assist in the rebuilding, becomes dissatisfied. This condition is one of the causes of the present study of trying to prepare a satisfactory extension rule.

Another condition to be taken into account when writing an extension rule is what is the most convenient method for the customer to pay his bill. Ninety-nine per cent of all public utility service has been rendered to and paid for by customers whose income is received monthly and whose bills are paid likewise. That was the most convenient and accepted method. Charges made monthly covering excess extensions to utility distribution systems to serve such customers would fit in the general method of making payments. But if in building an extension to serve a rural customer or farmer provision for making payments other than monthly is allowed it may make the securing of this class of customer easier and afford greater convenience to the farmer in arranging his payments, particularly that required for the extension. The farmer's income is neither regular by the month or year. Crop seasons prevent regular monthly incomes and crop failures prevent regular annual incomes. Generally the farmer desires to spend freely following good crop and income years and to be able to curtail expenditures during lean years. The merchant and banker serving rural customers realize this well.

Furthermore, the extension rule should, if possible, be so constructed that the existing rates will apply to the new customers and at the same time not cause the new capital to disturb the present rate base. The extension should also be made so that, if in the future the property of the utility is appraised and a new rate base is established, the charges to cover extensions will reflect the changed rate base.

A GENERAL EXTENSION RULE

With all the above conditions in mind the method of extending distribution systems as set out below is offered as a general extension rule. The amounts, constants, units, etc., used in the rule at any place are to be derived from the particular distribution system to

which the rule applies, and these can easily be obtained from the books of the system. Illustrations in the application of the proposed extension rule are given near the conclusion. The units shown in the figures and used in presenting the rule are arbitrary and are considered as those appearing in making an electric line extension, but following the explanation of the rule there will be shown how it will apply to three existing distribution systems, a water, a gas and an electric system. Assuming the investment in distribution system is \$25.00 per customer and that this will build 100 feet of two wire pole line the extension rule may read:

The company will make extensions to its present lines a distance of 100 feet to serve any customer, the cost of such extension being estimated to average \$20.00 and is called the "Free Limit extension." For customers requiring extensions greater than the Free Limit such extensions will be made by the company and for every 100 feet or major fraction thereof above the Free Limit extension the customer will have added to the monthly bill estimated on the standard urban rate applying to the class of service to be furnished an extension charge of 20 cents.

If the extension is made to serve more than one customer the extension charge will be prorated between the customers served on the basis of the number of 100 feet sections of the extension or major fractions thereof between each customer and the point where the extension is to be attached to the company's present lines after deducting a Free Limit extension from each customer. As customers are added or taken off the extension, the extension charge will be adjusted accordingly and prorated on the basis above described. As customers are added at an average of one for every 100 feet of the extension the point at which the extension is considered to be attached to the company's present lines will be moved forward accordingly.

EXAMPLES OF APPLICATION OF EXTENSION RULE

The following concrete examples together with the sketches attached and numbered likewise illustrate how the extension charge is to be applied. The present distribution line in all the figures is indicated by the dotted line and the extension by the solid line thus ———.

Assume an extension of 500 feet to serve the first customer called A (see fig. 1). There are five 100 foot units of length, which unit of length has been taken as the average length of line per customer the company now has in its distribution system to serve its present customers, and the average cost is \$20.00 per unit. The company agrees to bear the cost of one customer unit length for the new customer. This is called the Free Limit and is marked Fl-A, Free Limit

for customer A. To avoid disturbing the present rate base and to enable the company to furnish service to A at the standard rate, customer A should be charged an amount sufficient to pay interest and depreciation on the extra amount of money invested for him over that of the regular extension customer. For ease of keeping record and understanding the extra charge should be shown as so much for each unit of extension and the total billed as an extension charge added to the regular rate charge. The extension charge of 80 cents in this case is made up of four unit charges of 20 cents each (see fig. 2).

Assume a second customer B is added as in figure 2, the Free Limit or first 100 feet of the original extension becomes chargeable to B

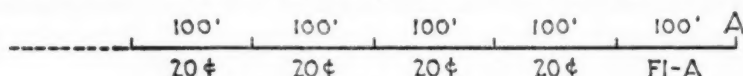


FIG. 1. EXTENSION CHARGE, A—80 CENTS



FIG. 2. EXTENSION CHARGE, A—60 CENTS, B—00 CENT

and the first customer's monthly extension charge will be reduced by one unit charge or to 60 cents.

If the second customer B is added in the second unit or 100 foot section of the extension made to serve the first customer the first customer's extension charge will be reduced to 50 cents and an extension charge of 10 cents added to the second customer's bill. This is shown in figure 3.

If the second customer is added in the third unit or 100 feet of the extension made to serve the first customer, the first customer's extension charge will be 40 cents and an extension charge of 20 cents added to the second customer's bill, as shown in figure 4.

If a second customer is added to the second unit or 100 foot section and a third customer, C, added to the fourth unit or 100 foot of the extension made to serve the first customer, as in figure 5, the first customer's extension charge will be $16\frac{2}{3}$ cents per month, the second customer's extension charge will be $6\frac{2}{3}$ cents per month, and the third customer's extension charge will be $16\frac{2}{3}$ cents per month.

If another extension unit of 100 feet must be made beyond the original extension to serve the third customer, C, the extension charges for each will be A, $26\frac{2}{3}$; B, $6\frac{2}{3}$; C, $26\frac{2}{3}$ cents; as shown in figure 6.

In figure 7 below a lateral extension is made two units or 200 feet in length to serve customer C.

The two additional units are chargeable to C only and the other units of the original extension prorated between those it is to serve.

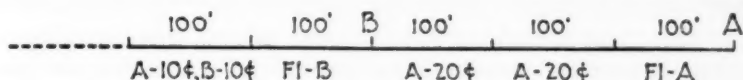


FIG. 3. EXTENSION CHARGE, A—50 CENTS, B—10 CENTS

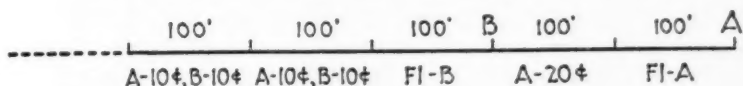


FIG. 4. EXTENSION CHARGE, A—40 CENTS, B—20 CENTS

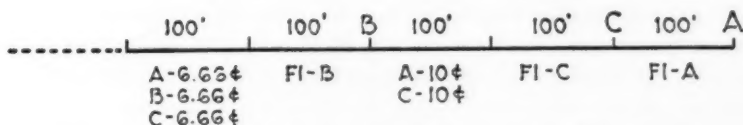


FIG. 5. EXTENSION CHARGE, A—16.66 CENTS, B—6.66 CENTS, C—16.66 CENTS

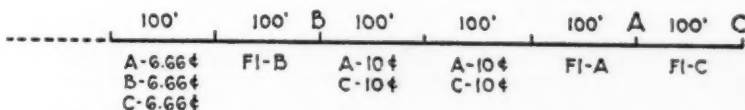


FIG. 6. EXTENSION CHARGE, A—26.66 CENTS, B—6.66 CENTS, C—26.66 CENTS

The unit is divided equally between those customers it serves, allowance of a Free Limit unit having been made for each customer.

Figure 8 shows how the extension charges are made with A and C attached at the same point. The results are the same as found in example 5 above.

If five customers were attached to the extension at the point A is attached, the Free Limit allowance would eliminate all extension charges.

In a similar manner an extension of any length may be made for any number of customers and by use of the extension charge the burden of the extension is properly divided between all customers served. As new customers are added the extension charge is easily readjusted. When there is an equivalent of one customer per unit of length for a part of the extension lying between some point on the extension and the point of connection of the extension to the main system the extension charge is cancelled for that part on which that average obtains.

If an extension requires three wires to serve a power customer a slightly higher and proper charge per unit of length may be made

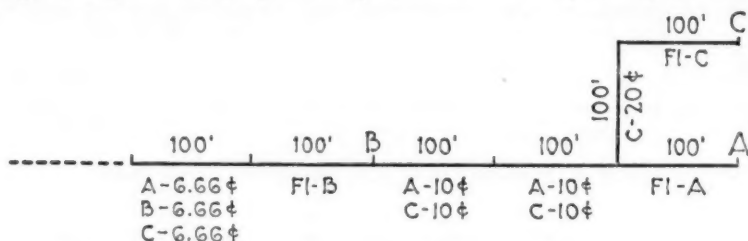


FIG. 7. EXTENSION CHARGE, A—26.66 CENTS, B—6.66 CENTS, C—46.66 CENTS

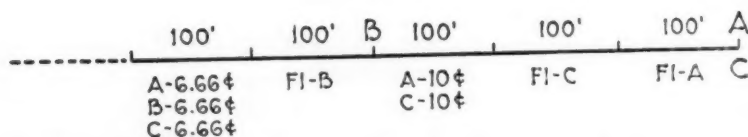


FIG. 8. EXTENSION CHARGE, A—16.66 CENTS, B—6.66 CENTS, C—16.66 CENTS

against such customers. Various classifications of customers may be made and the investment cost per unit length of line per customer determined.

This rule may be applied to serve rural customers as well as urban. The utility may not consider it wise to built a line to a farmer customer without asking the farmer to deposit a sum of money to pay for the cost of the line. If the farmer does pay for the line the question of ownership is brought up. The utility is the logical party to maintain and operate it. Should the utility be allowed to capitalize and earn on the line is a question often discussed. There are many conflicting conditions to consider. Under the proposed rule it is

suggested that the utility finance the extension. It can secure money more cheaply than the farmer and can immediately capitalize the investment. To safeguard the utility against a loss on the extension the farmer should be required to deposit with the utility a sum equal to the present worth of five or ten years payments of the extension charge, the value of the money being taken at about its cost from bonds. There is no doubt that the utility will deliver the service so the farmer's money is safely spent by him. Furthermore the farmer will make the deposit at a time when he feels able and then can enjoy the service at a reasonable monthly charge the five or ten years thereafter. If no new customers are added during the five- or ten-year period following the building of the extension the farmer can then at the expiration of that time be billed monthly for the extension charge and the utility has not assumed a risk. If the farmer happens to have a good crop he can go to the utility at any time and pay the present worth of the extension charge for any number of years he may desire. It is made to fit the farmer's method of paying his accounts, especially the larger accounts.

For short extensions, as urban or suburban, the customers will probably elect to pay the extension charge monthly as it comes due, their income being on that basis. Also the period of time to be covered by an initial deposit may be made three to five years, instead of ten. The utility assumes less risk in making urban extensions than it does in making rural because of the continuous growth of the city, which guarantees additional customers within a comparatively short time.

If additions are made to the extension or new customers are added to the original extension adjustments can be easily made to those customers who have paid the extension charge in advance.

How the rule applies to an electric, water and gas distribution system is shown below. The figures were taken from the records in investigations made for rate making purposes. Such items as Engineering and Superintendence, Injuries and Damages during Construction, Interest during Construction and Legal Expense during Construction were prorated between Distribution Mains and Services and all other Fixed Capital on the basis of money invested. The investment in Distribution Mains and Services so found were:

Water.....	\$66.09
Gas.....	\$72.31
Electric.....	\$27.20

The length of the lines of the distribution systems per consumer was:

	<i>feet</i>
Water.....	53.51
Gas.....	50.63
Electric.....	91.25

Applying the rule, the extension charge per month for each unit of length above the free limit length, allowing for interest and depreciation, 9 per cent on the water and gas lines, and 12 per cent on the electric, is:

	<i>cents</i>
Water.....	49
Gas.....	54
Electric.....	27

If an extension of 500 feet is to be made of the various distribution systems, the number of unit lengths will be:

Water.....	9
Gas.....	10
Electric.....	5

If the extension is made to serve one customer, one free limit unit will be allowed and the customer in each case will be billed for the following number of units.

Water.....	8
Gas.....	9
Electric.....	4

The monthly extension charges will be:

Water.....	\$3.92
Gas.....	4.86
Electric.....	1.08

If conditions are such that the utility furnishing the service is justified in requiring the customer to make a deposit sufficient to pay extension charge for five years, the deposit should be:

Water.....	\$202.72
Gas.....	251.28
Electric.....	55.84

If the customer should be allowed to pay the extension charges monthly, the total amount that would be paid in five years would be:

Water.....	\$235.20
Gas.....	291.60
Electric.....	64.80

The utility should have in most cases the power to determine the period of time the deposit should cover when application is signed for an extension and service.

If the customer were required to pay the entire cost of the extension, less one free limit unit, on the basis of the average cost of mains as used above, the deposits required would be:

Water.....	\$528.72
Gas.....	650.79
Electric.....	108.80

If the electric company above is requested to make a two wire extension $\frac{1}{2}$ mile in length to serve a rural customer, assuming the present unit length per customer is 91.25 feet, there will be 19 units of extension. One is to be built free by the utility leaving 18 units to be covered by an extension charge. Allowing 12 per cent for interest and depreciation the monthly extension charge per month is 27 cents or a total monthly extension charge of \$4.86. If the customer is required to deposit the extension for 10 years in advance the total amount will be \$437.59. The total amount that would be paid in monthly payments would be \$583.20 in ten years. This charge is based upon the city distribution system used above, where no deduction was made for street lighting service. By making proper deductions, as for street lighting and longer pole spacings, the extension charge will be less than is indicated above for rural extensions, possibly 30 or 40 per cent. The amount can be easily determined with sufficient accuracy to justly apply the rule.

If three phase service is required the extension charge can be increased proportionately to take care of it. The extension rule does not cover special equipment for substations as may be required by the customer, variation being required here as it is required in the urban territory.

The extension rule as given above provides that:

The company can definitely determine the basis for making extensions.

The customer can be definitely informed of how his charges are to be made for the service.

The extension charge can be paid in a manner suitable to all parties concerned, that is, if a part of the customers served by one extension desire to pay the extension charge monthly and others for a longer period, even though both classes of customers are served by the same extension, proper charges are made.

The extension charges operate jointly with the rates charged for service in producing the proper revenue and changes in the rate base are reflected in the extension charge.

The extension charge be based upon the property to which it applies.

The extension charge be automatically reduced as new customers are added and the resulting extension charge be equitably adjusted between the customers served.

CONTINUOUS VERSUS PERIODIC READING OF METERS AND BILLING¹

H. P. BOHMANN:² Meter reading is the foundation of the revenue of a water works and in order that the amount of water consumed may be intelligently computed it is essential that this work be accurately, honestly and frequently performed. At Milwaukee with 78,200 meters in service January 1, 1926, meters of small consumers are read monthly, meters of large consumers bi-weekly and contractors' meters weekly.

While the duties of a meter reader are primarily the recording of the registration of the meters, he has other functions or duties that are scarcely less important to the Department.

TESTING FOR ACCURATE REGISTRATION

These include testing of the meter to ascertain if it is properly registering. Only by frequent readings can the department have a check on the performance of the meters and by a proper method of reporting all meter defects and the immediate remedying of those defects by an efficient repair department can the department be in a position to render bills that are just and equitable.

Where many meters are in service thousands of accounts must be "averaged" each year on account of meters being temporarily out of order. The period during which a meter is not operating properly is greatly reduced by frequent readings of the meter, with a result that with monthly readings the average length of time a meter would be out of order before being discovered would be but 15 days. Bills when rendered therefore reflect to a greater extent the actual consumption than if a meter is out of order the greater part or all of the period covered by the bill.

Frequently when consumers receive "averaged bills" complaint is made in regard to the quantity of water consumed. When the consumer can be shown that only a small fractional part of the period is "averaged" and the balance actual registration with the short

¹ Topical Discussion before the Buffalo Convention, June 7, 1926.

² Superintendent of Water Works, Milwaukee, Wis.

averaged portion on the basis of the actual registration, it is usually an easy matter to convince him as to the equity of the charge. This applies especially to large consumers where the amount involved is considerable.

All meters of large consumers in Milwaukee are read bi-weekly thereby still further reducing the average length of time the meter is out of order and lessening the time covered by the average when computing bills. Meters set for construction purposes are read weekly, which gives us an excellent check on the consumption on account of the great variations during different periods as the construction progresses. It prevents in a great measure tampering with the meter, either intentionally or otherwise.

Frequently when extensive leakage exists and the meter is recording at or near capacity for some time, some part of the meter gives out and the meter stops registering. This is especially true when meters have been in service for a long time. At a normal rate of consumption a meter might function properly for a long time. When an unusual strain is put on it, however, some part usually gives out. Unless a meter is read frequently no knowledge of such unusual conditions is discovered and a great deal of revenue may be lost to the department.

DETECTION OF UNUSUAL CONSUMPTION

Secondly, investigation of the cause of unusual consumption and notification of the consumer are assured.

While the water meter furnishes the most accurate basis for charging for water, it serves another important purpose, namely, that of a safeguard and protection to the consumer as well as to the water works in case of leakage, etc. It measures accurately the consumption and all extraordinary conditions existing are early reflected by the registration of the meter. Again frequency of readings has the advantage of bringing discovery with the least delay and affording an opportunity to the consumer to avoid excessive water bills.

At Milwaukee, whenever an unusually large registration is shown by meter, a notice is left with the owner, if he resides on the premises or mailed to him if he does not, calling his attention to the extraordinary condition and asking him to investigate without delay to avoid a large bill. On account of reading meters monthly and large meters bi-weekly a great saving is shown, as the average length such condition exists will not exceed 15 days for small consumers and 7 days

for large consumers. This is especially valuable where underground leaks exist that find their way into a drain or sewer and do not show on the surface.

For example, take a small consumer in moderate or poor circumstances whose water bill amounts to only a few dollars annually. Suppose an underground leak existed that did not make itself apparent on the surface or in any other way. If the meter is read frequently the very next time the reader called after such a condition developed he could not help discovering it. By notifying the owner at once, steps could be taken immediately to have the necessary repairs made with but small loss. On the other hand, if this condition had been allowed to exist for three or more months before discovery, a tremendous bill would have accrued, with a hardship on the consumer with benefit to no one. While it would temporarily increase the revenue of the department, it would leave a bitter feeling in the mind of the consumer toward the department. Even a very small leak running 24 hours a day will in three months time amount to considerable.

At Milwaukee approximately 26,000 "large consumption" notices were delivered to consumers or owners during the year 1925, which has resulted in a great saving to consumers.

We have on file many letters of thanks from consumers for calling their attention to high water consumption. Consumers realize that the efforts of the department are to furnish the best possible service and to help them avoid unnecessarily high water bills.

Most complaints received are in regard to large consumption. With our frequent or continuous readings and close attention to conditions by meter readers, we are able to adjust satisfactorily all complaints and avoid controversies with consumers.

DETECTION OF VIOLATIONS OF RULES

Thirdly, policing of districts in regard to violation of the rules and regulations of the department is possible through frequent meter readings.

Meter readers are obliged to familiarize themselves thoroughly with every condition in their respective districts. While primarily engaged in reading meters and safeguarding the interests of the consumer, the meter reader also safeguards the interests of the department as well as that of the city in general. He must see that

contractors have proper permits when using unmetered water, report all illegal opening of fire hydrants, leaks or breaks in mains, etc., or any other violation of the rules and regulations of the department. They co-operate also with other divisions and departments of the city service in regard to sanitary and health conditions in their district.

Water meters frequently run over, i.e. reach their full dial capacity and repeat one or more times each quarter. Where meters are read only periodically, it is practically impossible to compute accurately the amount of water consumed, as it is not evidenced by the meter that such had been the case and considerable revenue may be lost to the water works in this manner.

By reading meters continuously the department is in a position to employ meter readers permanently, insuring accuracy and efficiency in the performance of their duties.

Frequent readings of meters protect the water works, insofar that they eliminate almost entirely the tampering with water supply or meters. Taking readings infrequently or at long intervals affords an opportunity for all kinds of liberties with the water supply or meters by unscrupulous consumers and many times unintentionally by honest consumers, with a result that the department may lose many times the cost of additional inspection. If water supply or meters are tampered with, it leads to almost immediate discovery before the consequences are considerable.

It is generally conceded that where meters are not read frequently, when leakage occurs some abatement or adjustment of the amount of bill should be made and usually on a 50 per cent basis. It is claimed that approximately 3 per cent of the total assessment for water rates is so rebated where that practice is followed. Assuming this figure on an annual assessment such as the city of Milwaukee, the amount of loss to the water works due to such adjustments would approximately amount to the entire annual expense for reading meters on a monthly basis. As a matter of fact the abatements made by the city of Milwaukee due to leakages do not average \$50.00 annually.

A water works, especially if municipally operated, should not endeavor to make money, but rather to give the maximum of service at the lowest rate to the greatest numbers of consumers.

That Milwaukee is not the only city that believes in continuous meter reading is evidenced by an extract from *THE JOURNAL*, Vol.

1, No. 2, June 1914. The report of the Committee on Tabulation of Water Rates, etc. shows that, of a total of 257 cities, 177 or 69 per cent read meters monthly, while only 69 or 27 per cent read meters quarterly.

GENERAL PRACTICE IN FREQUENCY OF METER READING

The above report being too ancient to reflect present day practice, questionnaires were sent to 37 cities having a population of 100,000 and over. Thirty-two replies were received, representing a total population of 11,617,000 with 1,701,200 meters in service, an average of 86 per cent of water consumers metered. Abstracts from the above revealed the following:

Frequency of meter readings

Small consumers:

Semi-annually.....	1
Four-monthly.....	2
Quarterly.....	16
Bi-monthly.....	3
Monthly.....	10
Total.....	32

10 or 31 per cent favor monthly reading
 3 or 9 per cent favor bi-monthly reading
 16 or 50 per cent favor quarterly reading
 3 or 9 per cent favor less frequent reading

Large consumers:

Quarterly.....	7
Monthly.....	23
Bi-weekly.....	2
Total.....	32

7 or 22 per cent favor quarterly reading
 23 or 72 per cent favor monthly reading
 2 or 6 per cent favor more frequent reading

Do you favor monthly readings?

15 or 47 per cent favor monthly readings
 13 or 41 per cent favor monthly readings large consumers only
 4 or 12 per cent favor less frequent readings

All replies received show that consumers are notified in case of leaks, large consumptions, etc. This is consistent practice as far as

large consumers are concerned, for 25 or 80 per cent read large meters monthly or oftener. How this works out with the smaller consumer is hard to determine, as only 10 or 31 per cent read small meters monthly.

It would, appear therefore, that the small consumer, to whom perhaps the large bill is a greater hardship than to the large consumer, is not getting the same protection through the notification of large consumptions, leaks, etc., notwithstanding the fact that the small consumers represent a great majority of water takers. It is a well-known fact that, where leakage exists, it becomes greater the longer it exists.

On the other hand, where meters stop registering or become out of order, or read but periodically or infrequently, difficulty is encountered in regard to computing properly the consumption due to seasonal or other conditions. Again the small consumer is not getting the proper protection and unfair and unjust assessments to the department as well as to the consumer may result.

Abstracts from the replies received prove conclusively that it is to the best interests of all concerned to read the large meters, or the small minority, frequently. Why should it not then also be to the best interests of all to read the small meters or the great majority just as frequently?

Eighty-eight per cent of the cities reporting are in favor of reading large meters monthly, while 47 per cent also favor monthly readings for small meters, with only 12 per cent in favor of less frequent readings.

If meters are read only as frequently as bills are rendered, it does not tend to the best service. Usually readings are taken during the final month before the billing period as rapidly as possible in order to get out the bills. Therefore, readings taken during the interim period afford readers better opportunity for observing conditions, testing meters, etc. It should be the ambition of a meter reader to get his route in such shape during the interim so that when taking the final readings for billing he will have as little trouble as possible. Where bills are rendered infrequently, I believe it to be false economy to use that as a guide or proper period for reading meters. No direct relation exists between the reading of the meter and the rendering of the bill.

The following is a résumé of the advantages of continuous over periodic readings of water meters.

1. Meter defects discovered shortly after occurrence.
2. Reducing period "averaged" when computing accounts, so that bills when rendered reflect as nearly as possible actual consumption.
3. Large consumptions, leaks, etc., discovered shortly after occurrence, affording consumer an opportunity to have repairs made and avoid excessive bills.
4. Minimizes difficulty in adjusting complaints about excessive bills.
5. Prevents violations of rules and regulations, illegal use of water by contractors, etc., coöperation with other departments.
6. Permanent employment for field force, thereby increasing efficiency.
7. Prevents tampering with water supply or meters.
8. Makes abatement or adjustment of large bills due to leaks unnecessary.

CONTINUOUS VERSUS PERIODIC RENDERING OF BILLS

Since the establishment of the Milwaukee Water Works metered water rates at this city have been collected quarterly. On January 1, 1926, 78,200 bills were issued and, with the additional accounts to be added during the year, approximately 320,000 bills will be issued and collected during the current year.

There has been no demand from a single individual for a change from the present system which has stood the test for fifty odd years under many administrations. It must have, therefore, some real merit.

Various plans have been investigated from time to time without finding a better one and all of them are more costly.

An abstract from the replies from 32 cities, as to the frequency of rendering bills, is shown below:

Frequency of rendering bills

Small consumers:

Annually.....	2
Semi-annually.....	5
Quarterly.....	18
Bi-monthly.....	1
Monthly.....	6
Total.....	32

- 6 or 19 per cent favor monthly billing
- 1 or 3 per cent favor bi-monthly billing
- 18 or 56 per cent favor quarterly billing
- 7 or 22 per cent favor less frequent billing

Large consumers:

Semi-annually.....	2
Quarterly.....	11
Monthly.....	19
Total.....	32

19 or 60 per cent favor monthly billing
 11 or 34 per cent favor quarterly billing
 2 or 6 per cent favor less frequent billing

In 56 per cent of the cities reporting quarterly billing is favored for small consumers, while 60 per cent favor monthly billing for large consumers. Seventy-nine per cent of the cities favor monthly billing for both small and large consumers, while 90 per cent favor quarterly billing.

Opinions differ greatly as to how often bills should be rendered, varying all the way from monthly to annually, but differ only slightly from the actual practice as reported below.

Small consumers:

Annually.....	2
Semi-annually.....	4
Quarterly.....	16
Bi-monthly.....	1
Monthly.....	9
Total.....	32

9 or 28 per cent favor monthly billing
 16 or 50 per cent favor quarterly billing

Large consumers:

Semi-annually.....	3
Quarterly.....	12
Monthly.....	17
Total.....	32

17 or 53 per cent favor monthly billing
 12 or 38 per cent favor quarterly billing

I believe that both small and large consumers should be billed at the same time, as that makes for the greatest economy.

Railroads, tanneries and other large manufacturing establishments have a large number of meters in various parts of the city, some rated

as small and others as large consumers. If small consumers are billed less frequently than large consumers, they would receive some of their bills monthly and others quarterly, causing considerable confusion in their accounting department.

The period between billings should be of such duration as to meet every local condition of the community to which it applies.

If large consumers are billed more frequently than small ones, there is additional expense.

A certain amount of confusion is likely to arise due to accounts passing either side of the dividing line between those that are billed frequently and those less so. An account may be in one class for a certain time and again in another at other times, due to increases or decreases in consumption.

In cities where water rates are not assessed against the property and the right of lien does not apply, but rates are assessed against occupants, a goodly per cent of whom are tenants and frequently change, frequent collection may be desirable.

Cities having a minimum or a service charge sufficiently large may be justified in more frequent collection on account of the revenue involved.

Frequent collection is not so vital as frequent reading and perhaps the amounts of bills would be the best obtainable guide as to the procedure to be followed in that matter.

Water bills at Milwaukee, unlike telephone, electric light and gas bills are of much smaller amounts; in fact, so small that it would not justify monthly billing and collection. A table prepared as of January 1, 1926, shows that at our present rate, out of 78,200 accounts, 71,500 or 91 per cent would average less than \$1.00 per month. Of these 1250 would pay less than 23 cents per month, 6030 between 23 and 30 cents per month, 15,830 between 30 and 42 cents per month and 14,680 between 42 and 56 cents per month; amounts too ridiculously small to warrant the expense of monthly collection.

It is evident that the more frequent the billing the greater the expense must necessarily be for billing and collection.

J. E. GIBSON:³ I can fully endorse the statements presented by Mr. Bohmann as to the many advantages of the continuous reading and billing of meters as opposed to the periodic readings. It certainly

³ Manager and Engineer, Water Department, Charleston, S. C.

reduces the congestion in the office, keeps the office force occupied under a systematic routine, and eliminates materially the possibility of errors, due to the fact that the work goes along in a systematic and orderly manner without those periodic rushes of speed and long hours.

When the City of Charleston purchased the private water company, I found that we had a chaotic condition. The industrial or commercial meters were read monthly and billed accordingly; a percentage of the domestic meters were read quarterly and billed immediately after reading; the flat rates were billed quarterly; then at the end of the year, the domestic consumers were given an adjustment provided they had not used the minimum for the twelve months of \$12.00, but had overpaid during some quarter, contract being made for a yearly rather than for a quarterly period.

The first resolution adopted by the Commission was one authorizing us to meter everyone and to do away with all flat rate consumers. We proceeded to district the city into nine major districts with a 10th district which is known as the "monthly" or "commercial" district, where meters, on account of their large consumption, are read monthly. These districts were then sub-divided into routes and the routes were limited not to exceed 150 meters to a route. The order of reading is to commence at the first district during the first month of the year, reading district No. 1 in the first ten days of the month; district No. 2 in the next ten days; and district No. 3 in the next ten days. Then proceed to the 4th, 5th, and 6th districts in the second month of the quarter, and the 7th, 8th, and 9th districts in the third month of the quarter, repeating the above order at the beginning of the fourth month. As we have laid it out, this means that we read and bill about 200 meters each day; then toward the end of the month, we have the monthly district to read, which increases the work for only the first few days of the succeeding month.

Bills are due and payable within ten days of rendition, so it will be seen that ordinarily we read about 200 meters each day. The following day these bills are made out and mailed, and within the next ten days probably 90 per cent are paid.

The total number of bills paid in dollars is summarized each day, which added to the previous amount billed and collected, gives the total amount of water in cubic feet and dollars billed up to and including that day, with the total amount of rates, so that in effect we carry a perpetual balance. At the close of each business day we

know the exact amount of money owing the department for water billed. We found this, as before stated, to equalize the work in the office, reduce the number of errors, and give the Department ample working funds to discount bills and meet its obligations promptly.

A record is kept of the errors made in reading, billing, and collecting. At first the keeping of this record was objected to by some of the employees, but after they found that the purpose of it was not to use it as a lever to jack them up or scold them for dereliction of duty, but rather to foster a spirit of reducing errors, it met with the approbation of all, with the result that we have greatly reduced errors in all departments. I think during the year 1925 the total number of errors due to meter readings (approximately 50,000 readings) was only 15. Of course, there may have been more, but, if so, we did not catch them. I think you will agree with us that this is an enviable record, and while we hope to reduce errors in the future, it will be pretty hard to do so.

W. Z. SMITH:⁴ I had a question in my mind that I wanted to ask Mr. Bohmann. I was struck with the remark in reading his paper to the effect that he had so many bills that were less than a dollar per month. May I ask Mr. Bohmann if you have a minimum monthly charge or a quarterly charge for water in Milwaukee?

H. P. BOHMANN:² We have not, but we have a service charge of \$2.00 a year. The average householder does not pay to exceed \$8.00 a year, which includes the service charge, regardless of the size of the meter or service pipe. We have a uniform rate for everybody, whether he uses a thousand gallons or a million gallons. The small consumer gets his water at the same rate as the large consumer. We have one consumer who pays eighty thousand dollars a year. You pay 50 cents a quarter, whether any water is consumed or not, but when you do consume water, you pay at the rate of 7 cents per 100 cubic feet. We took twenty family homes in each section of the city and they averaged only \$6.00, which included the service charge. We counted 120 homes.

W. S. PATTON:⁵ I agree with Mr. Bohmann that it is a good plan to read the meters monthly, but it requires considerable extra labor

⁴ General Manager, Water Works, Atlanta, Ga.

⁵ Manager, Water Works, Ashland, Ky.

to bill monthly. In Ashland, we read our meters monthly, but we bill quarterly and I think we save a lot of trouble and considerable expense. After the meters are read between the quarterly collections, we send a notice to those who show an unusually large consumption of water. It runs something like this; "since a certain date, so many thousand gallons of water have passed through your meter. It would appear that there is some leakage in your plumbing. The water works is not responsible for the size of your water bill, but is pleased to coöperate with you in keeping it at the minimum." This has made many friends for us at Ashland. The only improvement I can see is that, if we were to divide our consumers into, say, three sections and bill one-third each month, I believe we would have the ideal arrangement. A great many of our consumers use only about a dollar or a dollar and a half's worth of water a month. It seems hardly worth while to mail them a bill for such a small amount. A quarterly bill is no hardship on the consumer and saves us extra expense.

W. Z. SMITH:⁴ In Atlanta, we have a minimum monthly charge for consumers, the smallest bill rendered being for \$1 per month. The minimum is larger for larger consumers. It is based on the size of the water connection. We have about 45,000 accounts. In keeping these accounts, we employ what is known as the daily billing system. The city is zoned into twenty-five zones. They are indicated by letters, using each letter of the alphabet with the exception of the letter I. We read the meters in one zone each day, starting with zone A and continuing through the alphabet, winding up with zone Z. We render the bills on a zone each day. Of course, the zones do not each pay up fully on the day due, and they overlap. As the coupons are brought in, they are distributed in the zones, so that when the discount period has expired we have all of the payments of that zone properly distributed. By noon of the following day we have all of the delinquencies recorded, so that they can be immediately notified. The whole process results in our completely clearing about 1700 accounts a day through our office. We do not keep consumers' ledgers. We use the coupon system entirely in handling our bills. It is all carried into a control account, so that we know at the close of business each day the charges on our books and the balances of unpaid bills.

We are strongly in favor of billing the consumers monthly for their

water bills. We take the position that, if it is well for a gas or an electric or a telephone company to collect their bills monthly, it is just as good business for a water company to collect bills monthly. We take the position that a water company is rendering a public service and that the consumer is entitled to know each month how much his water bill is. If he has a large bill, the result of leakage or waste, he is entitled to a notice of this fact. In carrying out that idea, each meter reader is supplied with a book of blank notices. When he reads a large bill, knowing that he is required to leave a notice with the consumer of this large bill, he is more careful to know that he is correct, for he realizes that there is likely to be a request for an examination of the service and he would not like to be caught in error. He leaves a notice with the consumer, and if the service is not one that it would take too long a period of time to inspect, the reader goes in and examines such fixtures as are available, bathroom, toilet and washstand, sink, etc., to see if there is any visible leak. He calls direct attention to this leakage, thereby giving to the consumer every advantage possibly in rectifying the trouble and stopping excessive bills. Since we ourselves have adopted the system of daily billing, the power company in Atlanta have likewise adopted the system and the same is true of the gas and electric bills.

H. P. BOHMANN:² We have similar machinery. The skeleton bills are prepared by the addressograph and then filled out on the billing machine. With our flat rate there is practically no checking necessary, because the machine accumulates the cubic feet and the total amount. If you get out a thousand bills, you multiply the quantity by the rate. If it balances, no checking is necessary. It seems to me your system has some disadvantages where you have a ledger card and the clerk who has charge of that account can see if there is a falling off of that registration. Apparently, you do not assemble those different readings, do you?

W. Z. SMITH:⁴ We carry that on the route book itself. We have on the account of any water consumer by the month, the monthly consumption in one column on the route book of his water for the last year, as a guide to the meter reader, and to the clerical force in charge of this account. Each month, when the meter is read, the quantity of consumption is carried into the next column, so that they have it before them all the time in the meter reader's book.

H. P. BOHMANN:² Who watches out to see whether the account is falling off?

W. Z. SMITH:⁴ The control clerk in the office bills from the report of the meter reader. If the account is falling off, he brings it over to the chief of his division, who has an investigation made until he is satisfied there is no loss.

H. P. BOHMANN:² I do not agree with you as to the monthly billing. In Milwaukee the telephone bill is \$3.75 for the average dwelling, and the water bill is not 75 cents. That would hardly justify getting out 78,000 bills every month.

W. Z. SMITH:⁴ Our rate is different from the rate of Milwaukee. Therefore, we feel justified in billing monthly. We have about 20,000 accounts that run above the minimum rate and the monthly bills of many of our domestic consumers bills run from \$5 to \$60 a month.

H. P. BOHMANN:² On a meter basis?

W. Z. SMITH:⁴ Yes. We have a few consumers whose bills run nearer a hundred dollars a month on the meter basis for their domestic water.

A MEMBER: Do they run a brewery or something of that sort?

W. Z. SMITH:⁴ Swimming pools, etc.

MUSCOL BURNETT:⁶ I should like to ask Mr. Bohmann about his rates. Is there not at present a frontage or property charge in Milwaukee that goes with the water?

H. P. BOHMANN:² Do you mean for the water pipes?

MUSCOL BURNETT:⁶ Yes.

H. P. BOHMANN:² Yes, there is a property charge on a frontage basis for laying a six inch water main. During the last sixty years

⁶ President, Water Company, Paducah, Ky.

the property owners have contributed about two million dollars out of the eight million dollars spent for this system.

MUSCOL BURNETT:⁶ They are not paying quite as much as in Atlanta, but still they are paying more than the minimum rate.

H. P. BOHMANN:² The average householder pays about \$6 a year.

MUSCOL BURNETT:⁶ And he pays for the water pipe?

H. P. BOHMANN:² A few years ago the investment was 60 cents a front foot; figure the interest on that, and it would be very small. On the other hand, the water department transferred last year 300,000 dollars to the city treasury.

D. C. GROBBEL:⁷ We changed our system or method of accounting and meter reading, in the past three months. We finished it on the 15th of March, making the change in all the bookkeeping equipment. Some wanted to put in the Baltimore system with stub accounting. I believe stub accounting is all right for a private water company, but not for a municipal department that has a lien upon the premises for the water. It seems to me that a historic record is necessary at all times when you want to place a lien upon real estate. The equipment agents could not impress me that they had such a historic record in a bunch of stubs that was piled up in the garret or basement or were thrown away after the third year. For that reason we in Detroit adopted the historic record, in other words, a card system with ledger cards. We also equipped our establishment with about 40 or 50 thousand dollars' worth of new equipment, changed our methods of handling the accounts, changed our methods of reading meters, and from three districts we jumped to thirty-six districts. In other words, we have continuous readings and we do get away with 230,000 meter accounts every three months, or practically 75,000 accounts every month. We believe that we have a very good system. We read meters monthly, that is, meters 3 inches and over. We have many meters in Detroit that run 3 to 4 inches. These are read monthly for check reading, but I cannot see any convenience or any good in billing monthly, because labor is too expensive in Detroit to send a bill for 45 or 50 cents to probably 80 per cent of the consumers.

⁷ Assistant Secretary, Board of Water Commissioners, Detroit, Mich.

A MEMBER: I would like to ask the gentleman from Milwaukee what time expires from that of reading of the meter until the bill is delivered?

H. P. BOHMANN:² On the first of June we begin reading. The bills are issued on the second. The meters read on the second are billed on the third, so that by the end of June all meters are read and the bills are made out and ready for delivery. Then the meter readers deliver the bills. It takes about five days to deliver the bills.

A. COLLINS:³ We have used the district system since 1913, dividing the city into meters from an inch down and billing and reading them quarterly. Anything over an inch is read and billed monthly. We have a service charge according to the system of the meter, and the rate is added to that. We found an advantage in that and I think it is a good policy. It enables you to keep down your rate. The lower the rate, the less friction you have with the public. We have about 55,000 accounts, and 90 per cent of those are quarterly. We have been able to handle our cash-in with one cash window. We find it very important to keep a ledger account, for the conditions on property are changing. They are adding ice machines, which we find to be quite a cause of increase of water and other conditions are changing. In that way we have a continuous account and we find the first indication of danger. If the meter reader finds that the consumption is increased, he immediately investigates and leaves a written notice on the property. The consumer then comes into the office with an apology and a repair slip to certify that the repair is made. On the larger meters, we bill, as I say, monthly and put in a stop rate. We were influenced in that by the peculiar situation in St. Paul. We have an artesian basin there, and it is estimated that over 35 or 40 per cent of the water is taken from private well supplies. You cannot stop that legally, I guess. We found, for that reason, that having a service charge caused very little friction. We were afraid of it at first, but it was explained to the people that it enables us to keep down the rate and in the sprinkling season there was no waste on the property. Now we find a necessity for keeping those ledger records to show how recently we have changed the meter on that property and whether there is a condition there that requires correction.

³ Water Commissioner, Niagara Falls, Ontario, Can.

EXPERIENCES WITH STORAGE RESERVOIRS AT LOW LEVEL¹

BY WILLIAM W. BRUSH²

New York has a diversified supply and we have had experiences with reservoirs at virtually every level, from full and overflowing in flood time to empty. Some of the experiences are interesting. They may be helpful to others who have had similar problems and perhaps have not solved them in just the way we have and others still who have not yet had those problems and will ultimately have them.

RESERVOIRS IN THE CROTON SYSTEM

In the Croton system there is the long, narrow, rather deep reservoir known as Croton Lake, about twelve miles in length with an available capacity of thirty thousand million gallons and about eight thousand million gallons unavailable.

Above that reservoir there are some ten reservoirs on the different branches of the Croton River, making the total available storage in that watershed one hundred and four thousand million gallons.

On Long Island there are virtually no reservoirs that amount to anything. Our big reservoir on Long Island holds, when full, just under 900,000,000 gallons, so we have virtually no problem that would develop from reservoirs that are empty.

Turbid waters

In the Croton, in the earliest years, there was the one reservoir formed by the old Croton Dam. It is about thirty-four feet from the top of the old Croton Dam to the level of the new Croton Dam and about three miles from the old dam to the new dam. Back of the old Croton Dam there was a storage capacity of two thousand million gallons and with this small storage a fairly substantial stream flow gave dirty water at the intake. This condition continued until

¹ Presented before the New York Section meeting, December 29, 1926.

² Chief Engineer, Department of Water Supply, Gas and Electricity, New York, N. Y.

there was sufficient storage in the Croton to permit of sedimentation taking place before the water was delivered.

Even as late as 1910 and 1911 we had a good deal of trouble with Croton turbidity. When the present Croton Lake was utilized, the question came up of how to handle the Croton supply and until about 1911, this was accomplished by drawing down Croton Lake and making thereby available its storage to hold any heavy run-off which might occur. That method gave insufficient storage capacity and each spring a turbid supply was delivered. About 1911 that system was changed and a careful determination was made of just how much each one of the reservoirs above Croton Lake should be lowered so that the reservoirs would all fill simultaneously, assuming that the run-off was uniform per square mile. Croton Lake was kept full or nearly full under that system and thereafter, there was very little trouble with the turbid water from this source. Croton watershed has no extensive clay banks to furnish fine clay or colloidal clay that will remain in suspension for a long time in the water. With Croton Lake full and with the reservoirs above it drawn down so that the first flood flows can be used, we have found that the necessary sedimentation and clarification take place before the water reaches the main intake. The main intake at the new Croton gatehouse is just below the site of the old Croton Dam but the greater part of the water is taken at the Croton Dam and it is sent back about three miles through the old Croton aqueduct under the bottom of the lake to the new Croton gatehouse. That puts the aqueduct under an internal pressure, but the pressure is less than the external head of water and therefore there is no bursting pressure on the old Croton aqueduct between the new Croton Dam and the gatehouse three miles upstream. By taking in about three-quarters of the supply at Croton Dam, we are able to get the clearest water and the most satisfactory supply.

Troubles with vegetation

During the time that Croton Lake was being operated at a lower level, we had the exposed areas on which vegetation would spring up and, as these areas were exposed in the late spring or early summer, there would be a very substantial growth. The question came up whether we would or would not have trouble from this vegetation when the areas were again flooded, but no trouble developed. The vegetation looked heavy but when it dried in the fall it would not

burn as the grass and other vegetation were not sufficiently closely matted so that the fire would spread. The upper reservoirs never had given us any trouble from this yearly growth of vegetation.

Under the plan of operation for the last eight years water has flowed each spring over the dam. Virtually everybody who is interested in water supply, and does not know much about the question of the available supply, thinks that because the water goes over the Croton Dam the system is not being operated profitably, and these persons wish to stop the water going over the Croton Dam.

If a water system is so operated that no water passes over the dam that system is being overdrafted for the greater part of the time. If New York City did not allow any water to go over the Croton Dam and did not allow any water to go over the Ashokan Dam—and none has gone over since 1917 when we first started to operate—it would mean that New York City would not have a supply available during periods of low run-off, because we would be utilizing the average yearly flow of the river which is about double the lowest yearly flow.

The wave action on the shore has never been troublesome in Croton from the viewpoint of turbidity. The sediment stirred up by wave action settles out very quickly after a high wind has subsided. The flood flows have been taken care of fairly well by the upper reservoirs and when the water comes over an upper reservoir dam it is usually a fairly clean water which flows down into the upper end of Croton Lake and then travels slowly down in the lake. By the time it reaches the dam it has become sufficiently clarified by sedimentation to be satisfactory.

My personal view is that there is no serious difference in the microscopic growth with reservoirs drawn down as compared with reservoirs held at higher level. When a reservoir is drawn down, if any particular growth that develops is troublesome, it is much easier and much less expensive to treat the water with copper and destroy the growth than if the reservoir is full.

Effect on bacterial content

The *B. coli* content is likely to be greater in the water reaching the supply if reservoirs are low at the time the heavy run-off occurs, but the *B. coli* are very satisfactorily destroyed by the chlorine treatment that New York has used. I believe very thoroughly in the double chlorination so that there is no question but what every particle of water which goes to the consumer has been subjected to

at least one effective treatment by chlorine. Chlorine machines work very steadily, but in any plant there is a possibility of an interruption for a few hours in the course of a year's time, and water that once goes by the only chlorination plant is never treated by the chlorine. With double chlorination there is certainly no probability that any part of the water will get by both treatment plants without having been thoroughly sterilized by chlorination.

RESERVOIRS ON THE CATSKILL SYSTEM

In the Ashokan reservoir of the Catskill system there is the east basin with a capacity of about eighty or ninety billion, and the west basin with some forty billion. The tributary watershed of the Esopus creek, which is the main watershed that delivers into the Ashokan Reservoir, delivers directly into the west basin. The east basin has only a small local tributary watershed of relatively few square miles. The total contributory watershed for the entire reservoir, without considering the Schoharie, is 257 square miles.

By connecting up the Esopus watershed with the Schoharie watershed, there have been added 314 square miles of watershed. The Schoharie water flows through the eighteen mile Shandaken Tunnel which obtains its water from the reservoir formed by the Gilboa Dam which was completed last July. When full this reservoir holds twenty thousand million gallons. Up to this November, the water was delivered into the Shandaken Tunnel by a diverting dam that formed a small pond of a few million gallons capacity. Under the conditions that existed prior to the completion of the Gilboa Dam we could deliver about four hundred and fifty million gallons a day as a maximum through the tunnel. Now the delivery with the reservoir virtually full was, as I recall, about six hundred and thirty million gallons a day.

Up to 1924, we only had the Esopus available and we have operated with a view of utilizing all the water that came off the Esopus watershed. That operation has been successful and we have lost no water from the Catskill System, not even the leakage from the reservoir which was alleged, by one of the New York dailies.

The city has taken from the Ashokan reservoir for a period of several months approximately between six hundred and six hundred and fifty million gallons a day prior to the completion of the Gilboa Dam, whereas the approximate safe yield of the two watersheds without the Gilboa Dam was four hundred and fifty million gallons a

day. That was a deliberate overdraft in the sense of drawing more than could be safely depended upon. We watched very carefully the contents of the reservoir in relation to the probable supply which could be obtained later in that year and subsequent years if we had a drought or low run-off period. We kept the draught so that by the operation of our pumping stations, by installing some emergency pumping plants further to utilize Croton water, and by the reduction in consumption that comes from house to house inspection and from appeals to the public, we would still be able to meet the needs of the city.

Unusual ranges in run-off

This year up to the end of October we had the lowest run-off of the twenty odd years that stream flow records are available in the Catskills; then, in November, we had the maximum run-off for the Esopus for that month since the records were first taken. We had on the average a thousand million a day come off the Esopus watershed during November. So this year has been a combination of very low run-off for the first ten months and very high run-off for the month of November, when we had a little over 7 inches of rain as an average.

With that system of operation, the Ashokan Reservoir level has varied very greatly. In 1923, just before the Shandaken Tunnel was finished, the reservoir was down below sixteen billion as against one one hundred and thirty billion as the maximum content. We intentionally drew it down on the basis of avoiding pumping because we expected that when the Shandaken Tunnel opened we would have, for the time being, a greater quantity of water than we would need with the pumping that we would normally maintain from the Croton and other sources.

The following June, 1924, we had the two basins practically full. There were one hundred and twenty billion in storage as against sixteen billion the preceding October.

With those basins drawn down we had the same experience as far as vegetation on the shores and the bottom was concerned, as we had in the Croton but there was no trouble from the vegetation. The waves would stir up some of the fine material previously deposited on the bottom as the reservoir was drawn down, but that material would quickly settle out and did not noticeably affect our supply.

In the spring, we were fairly fortunate in having enough clean

water in the reservoir to allow us to hold the turbid water in the west basin and draw on the east basin until we had the turbidity reduced from forty to ten parts per million. When that water was mixed with the water in the Kensico the resultant turbidity was normally between five and ten in the spring, so that we only had a very few complaints and those were from people who were unusually sensitive to a slightly clouded water.

Effects of 1926 flood flow

After we had the Gilboa Dam completed, there came this flood of the middle of November. On November 15 and 16, there was a rainfall that averaged in the Esopus a little over four inches, in the Schoharie a little under four inches, but was quite varied. It was as high as eight inches, approximately, at certain points in the water sheds. We have ten gauging stations in the Esopus, and the Board of Water Supply maintains eight in the Schoharie, the Schoharie being still under the jurisdiction of the Board of Water Supply. Those gauging stations showed that the greater part of the fall was along the divide between the Esopus and the Schoharie. The water came down with a high turbidity in both watersheds. I do not know what the maximum turbidity was; it was probably over a thousand. It became about one hundred and twenty as a maximum in the Gilboa Reservoir and also in the Ashokan Reservoir in the west basin.

That turbidity was caused by a very large percentage of finely divided clay and the clay banks are either more numerous or else more readily eroded along the divide where the greater part of the water fell than generally over the watershed, so that we had a greater percentage of fine clay in this turbidity than we had previously.

Today, six weeks after that storm, we still have about ninety turbidity in the west basin of the Ashokan Reservoir. The east basin was nearly empty at the time of the storm and we then continued to draw from the east basin until December 8 when the flow took place over the dividing weir, and from then on we had turbid water in both basins. In previous years we found that in about five weeks time the high turbidity had dropped to ten or below. Gilboa Reservoir was empty at the time of the flood and went up fifty-two feet the first day. At the end of a week the reservoir was within five feet of being full and where previously there had been a small pond there was a lake that was several miles long and perhaps half a mile wide, containing eighteen thousand million gallons. The maximum

flow from each watershed for twenty-four hours was very nearly the same figure, a little over eleven billion, and the highest rate of flow from the Esopus showed about twenty-five thousand million or twenty-five billion at the height of the flood. Those were, as you can see, very sizeable quantities of water.

Treatment with alum and soda ash

As a result of those high turbidities, we have operated with the addition of alum and very recently of soda ash, the soda ash being introduced at the rate of about half a grain per gallon at the head works, so as to raise the alkalinity of the water which is normally about seven or eight, and in that way obtain an alkalinity of about fourteen.

Dr. Hale made an experiment at the laboratory as to the amount of alum to be used. His samples showed clearly that under laboratory conditions about a grain per gallon was needed. With a grain per gallon you had virtually clear water after standing overnight, whereas with three-quarters of a grain the water would remain at a turbidity of about ten. This turbidity of around one hundred settled out to between twelve and twenty after three or four days standing in a bottle in the laboratory, and then remained at that point virtually continuously for two or three weeks. We have no hope, therefore, of the water clearing up in the reservoir for some time to come. None of us know just how long it will continue with high turbidity.

We cut down the flow through the aqueduct while we were experimenting with the introduction of the alum because we did not wish to take any chance of putting in any large quantity of water in the Kensico Reservoir which was so turbid that it would be unsatisfactory for use. The water flows into the Kensico Reservoir about three miles from the point where it is taken out. It travels through only a portion of the reservoir and, therefore, the full volume of the reservoir is not available for dilution or sedimentation.

During these experiments we have drawn the Kensico Reservoir down about five billion gallons. Now we are delivering about four hundred million a day and taking out about five hundred million, but after the first of the year we expect to go up to a delivery of five hundred or a little above this figure.

As the water now pours into Kensico it has the color of a brownish red paint. Within one hundred feet or so of the point where the water comes in you see a grayish or a greenish gray color to the

water and quite a sharply defined line between the turbid water and the water which has shown the effect of sedimentation caused by the addition of the alum. Along the shore where the water comes in, for a distance of several hundred feet, there is a band or strip of red water that represents the current which is created by the flow over the influent weir, but that travels rather quickly along that shore and then slowly moves down the lake. As it moves down the turbidity reduces very rapidly. We believe that we will have no serious difficulty in furnishing a satisfactory water under these conditions, but there is, of course, the possibility that the alum after settling out in the upper part of the basin might sometime later be stirred up through the changes of the water, due to temperature changes or possibly through wind action if the reservoir is low, but I see no reason why the alum should not settle out rather quickly. I doubt very much if we are to have trouble from it. This question will only be finally answered in the future.

Microscopic organisms

As to microscopic organisms in the Ashokan, we may have had a slightly greater number due to the low level at which we carried the reservoir. I remember talking with some of our force when we first started to draw down the Ashokan. The question was: what will happen and will we have any trouble? As nearly as I could see it would simply mean we were changing a big lake into a small one which most of you, if you have a reservoir say of ten thousand million gallons, would say was a fairly good sized reservoir. We never had a reservoir as small as that in the combination of the two basins, but we have had the east basin this year completely empty. It went down to the lowest level at which we could draw water out, and it acted simply as a smaller lake as we drew down the reservoir. We treated both basins with copper for the first time this fall because synura were present. Synura have been present many times before, but this year we were down to a point where it seemed advisable to treat with copper and the treatment was successful. The *B. coli* content has naturally been high, but even with the turbidity there has been a complete destruction by the application of chlorine at the head works.

Chlorination

During the summer time we operate another chlorination plant at the head of the Ashokan Reservoir, where the water from the

Esopus Creek and the Schoharie Creek flow into the reservoir. That plant was closed in the fall of the year when the summer visitors disappear and the pollution is thereby greatly reduced.

There is a further chlorination of the water as it leaves the Kensico Reservoir and at Ashokan and Kensico plants *B. coli* is absent in 100 cc., except for two or three times during the year, thus showing a high degree of purification. With the turbid water, the same effective purification has been secured at Ashokan. The clay is so finely divided that the chlorine is able to destroy any bacteria. Those clay particles, while very much larger than bacteria, are probably not brought together after they have been washed from their original bed, and I should think that there would be no bacteria concealed in them, as has been shown by a recent test when a sample of treated water was kept for a week, tested daily and showed no *B. coli* in any test.

Best plan of operation

In the operation of the reservoirs the question arises, where you have two basins such as we have in the Ashokan Reservoir, as to whether it is desirable to keep the west basin full when we have the water there to do so, and let the east basin go down, and then later have the waters coming down the creek flow into the upper end of the basin and let the water flow over the dividing weir into the east basin or to open the gate between the two basins and quickly draw the water from the west basin into the east basin, by the leveling of the waters in the two basins. The east basin could then be held in reserve to let the water clarify, using the west basin water. Later when flood flows come the water could be held back in the west basin as long as possible.

In the Department, some of us are inclined to believe that the better plan is to hold the water in the west basin and let the stream flow raise the water level slightly so it passes over the dividing weir into the east basin, but some believe that the other is the better way.

As the water rises rapidly in a reservoir there is a general stirring up of the contents by the vast amount of work that is done in raising the water level in a large reservoir say 20 feet in a day.

If the reservoir had been at the overflow level at the time of this unusual flood, presumably there would be a general mixture of the waters, but, with the ordinary flood, there certainly will be less work done in the way of producing current, if the excess water

is passing over a weir and the water level of the reservoir is raised a foot or two as a whole only, as compared with raising it twenty feet in the course of a day.

The hydraulics of the movement of the water in the reservoir under those conditions would tend to support the theory that better results would be obtained if the water passed from the west into the east basin over the dividing weir.

Generally we have been able to deliver a more satisfactory water each year than the preceding year. That is due in part to the greater experience that has been available as a result of the treatment given the reservoirs with copper sulphate and of the use of excess chlorine to destroy tastes and odors created by the small dose of chlorine destroying the microscopic organism without destroying some of the tastes and odors. It is also due in part to keeping down the turbidity a little more effectively, but generally that has not been a serious problem until now. From now on, with the Schoharie Creek delivering water of much higher turbidity than the Esopus, and especially a turbidity that will not settle out as rapidly, we shall probably have to treat each year for part of the year the entire supply with alum and soda ash. By so doing we probably will be able to give at all times a reasonably clear water without filtration.

DISCUSSION

A. E. HANSEN:³ Mr. Brush, as you know, I am quite interested in designing plumbing systems in New York City. For the past two years we have had a great deal of trouble probably due to the softness of the water from the Ashokan Reservoir, as compared with that in the Croton, so that we have been obliged to use brass pipes in our plumbing systems, especially on the hot water. When you speak about the addition of soda ash and alum, I am wondering whether that would necessitate also brass pipe for our cold water supply in the buildings. It is a very serious proposition to New York City people.

WM. W. BRUSH:² The probabilities are, Mr. Hansen, that after this season we will not have the low levels in the Ashokan Reservoir. This year was the critical year as far as the economy of lowering the Ashokan Reservoir was concerned. After this year, the average flow

³Hydraulic and Sanitary Engineer, New York, N. Y.

from the Esopus and the Schoharie watershed will be in excess of the water that we can take through the aqueduct which has a capacity of 660,000,000 gallons a day. Therefore, in the future, for a little more than half of the years there will be a waste over the Ashokan Dam. With the reservoirs full, we would have a much lower turbidity when the water reaches the intake chamber, and I doubt very much whether we will generally have to add any alum, except for a very short period.

The present time represents probably the longest time that alum will be added and the addition of the soda ash will restore the alkalinity and bring up the pH to about normal for the Catskill water. I would expect therefore that, while there might be for two or three weeks a slight increase in the rate of corrosion from the water that is now in the Kensico Reservoir and is coming through, such condition would not extend for any length of time.

I will ask Dr. Hale to talk a little more on this subject because he is more familiar with it than I am.

FRANK E. HALE:⁴ The amount of water that has gone into Kensico treated with alum alone is very slight compared to the water in Kensico. We expect that that water will mix with the other water so that the reduction in alkalinity will be very slight. With the soda ash added in equivalent proportion to the alum there should be no change in alkalinity in the water in the city. The alum will not stay in the water. It precipitates out as alum hydrate, as you all know, and will go down into the bottom of the Kensico Reservoir so that, if properly proportioned, the Catskill water will be no more corrosive after this treatment than it has been before.

⁴ Director of Laboratories, Mt. Prospect Laboratory, Brooklyn, N. Y.

PRELIMINARY EXPERIMENTS ON THE TREATMENT OF LAKE MICHIGAN WATER FOR CHICAGO¹

BY JOHN R. BAYLIS²

Experiments at Chicago were started primarily to determine the most efficient method of purifying the Lake Michigan water. With a turbidity that ranges from about 3 to 100 and averages over 10 for some of the intakes, and with pollution that requires a fairly heavy dose of chlorine, the clarity and taste are not all that is desired. Since the construction of the Buffalo filters, Chicago probably has the most turbid water now being supplied any large city in this country, with the possible exception of Milwaukee and Kansas City. The writer, however, has no information on the clarity of the water being supplied these two cities.

The enormous consumption of water in Chicago, together with a supply that is not so very bad, have been the main factors delaying filtration. This paper will not deal with the present quality of the water, or with reasons for starting the experimental work, but with the problems which will receive consideration in the investigation and the results of the experiments already conducted. Mr. John Ericson, City Engineer, and his associates have been considering filtration for some time. It was only after a definite program for filtration had been decided upon that the writer was employed to conduct the experimental work under the direction of Arthur E. Gorman, Chief Sanitary Engineer.

TENTATIVE PROGRAM FOR EXPERIMENTAL WORK

Every method of treatment and every type of filter that offers the possibility of being suitable for Chicago conditions will be investigated. The water must be delivered to the consumer clear, pure and palatable at all times. Palatability will be considered second only to purity and no method will be recommended that does not leave the water clear and palatable.

¹ Presented before the Illinois Section meeting, January 28, 1927.

² Physical Chemist, Division of Water Safety Control, Bureau of Engineering, Department of Public Works, Chicago, Ill.

The tentative program involves such problems as the effect of microorganisms on coagulation, removal of tastes and odors, removal of microorganisms, various kinds of coagulants, optimum chemical conditions for coagulation, the value of mixing in forming a flocculation, types of mixing basins, conditions affecting the strength or toughness of the coagulation, the production of rapidly settling floc, microscopical studies of coagulation, softening, capacity of settling basins, flow through settling basins, rates of filtration, sand sizes, filter underdrains, washing rates, surface wash, prevention of cracks and clogged places, mud balls, and perhaps a few other minor subjects and those which suggest themselves as the work progresses.

Some of the undertakings will prove impractical early in the investigation or of no value in so far as the Lake Michigan water and local conditions are concerned. To illustrate, slow sand filters probably cannot be considered on account of the high cost of land, yet the water probably could be clarified satisfactorily by this method of filtration. The removal of microorganisms is going to be one of the most serious problems with which we will have to deal. There is a limit to the shortness of filter runs beyond which it is not desirable to go.

LENGTH OF FILTER RUNS

When the filter runs are shorter than about sixteen hours they are getting below that period essential for efficient operation. The design should be such that a yearly average of not less than twenty-four hours is obtained between washings, except under unusual conditions. The runs usually should not be less than 16 hours for more than about 5 per cent of the time. It is desirable to have filter runs from forty to fifty hours, but the expenditure of a large sum of money is not warranted to extend the runs much in excess of twenty-four hours.

Lengths of filter runs, as a rule, are not given enough consideration in the design of filter plants, due largely to the fact that most knowledge of the design of rapid sand filters has been worked out at places having fairly turbid water. Coagulation of a fairly turbid water, together with a reasonable period of sedimentation, usually give filter runs in excess of twenty-four hours, which as stated is nearly all that is desired, but in the coagulation of a low turbidity water the problem of preventing short filter runs is not so simple. The time out of service for washing and the amount of wash water

are usually the factors receiving most consideration in determining the economical length of filter runs, but the writer is of the opinion that the increase in turbidity of the filtered water after washing is of equal importance. A number of tests at Baltimore³ show that the turbidity of the filter effluent is increased for a period at least one hour after the filter is put back into service. Should the average increase in turbidity be 1.0 p.p.m. for an hour, which is frequently the case in many filter plants, this would increase the general average of the filtered water by 0.1 with runs of ten hours. When an attempt is made to produce water with a turbidity not over 0.2, this increase is of considerable importance. It may be found that microorganisms are such a problem in the Lake Michigan water that some extreme measure, usually not resorted to in a purification plant, will have to be adopted.

LAKE MICHIGAN WATER EASILY CLARIFIED

The experiments so far conducted indicate that the lake water is easily clarified. Almost any of the extensively used coagulants would be suitable and economical. The water appears to be saturated with soluble silica and alumina and the addition of any amount of alum or iron will produce a precipitate. It is also saturated with calcium carbonate and is ready to precipitate this compound on the addition of a slight amount of lime; that is, it does not require the addition of a definite amount of lime before there is softening effect, as is the case with some waters. The lake water is already partially coagulated and a large percentage of the suspended matter settles out fairly rapidly. Figure 1 shows the character of the suspended matter usually found in the lake water. This condition of partial coagulation may not exist all the time, but the periods within a year's time in which it is in a finely divided state probably are few.

By filtering the water of a turbidity between 10 and 20 p.p.m., without the addition of a coagulant, through an experimental laboratory sand filter, the turbidity is usually reduced to 2 or 3 when using customary rapid sand filter rates. At certain seasons of the year it probably will be reduced still more, although the writer has no hope of it being reduced to the desired standard of 0.2.

The problem of coagulation and clarification appears to be simple,

³ Baylis, *This Journal*, 15: 673, June, 1926.

unless the coagulation produced is of such a weak structure that it will readily pass the filter beds in the colder months, as at a number of filter plants. The problem is not going to be whether alum, iron

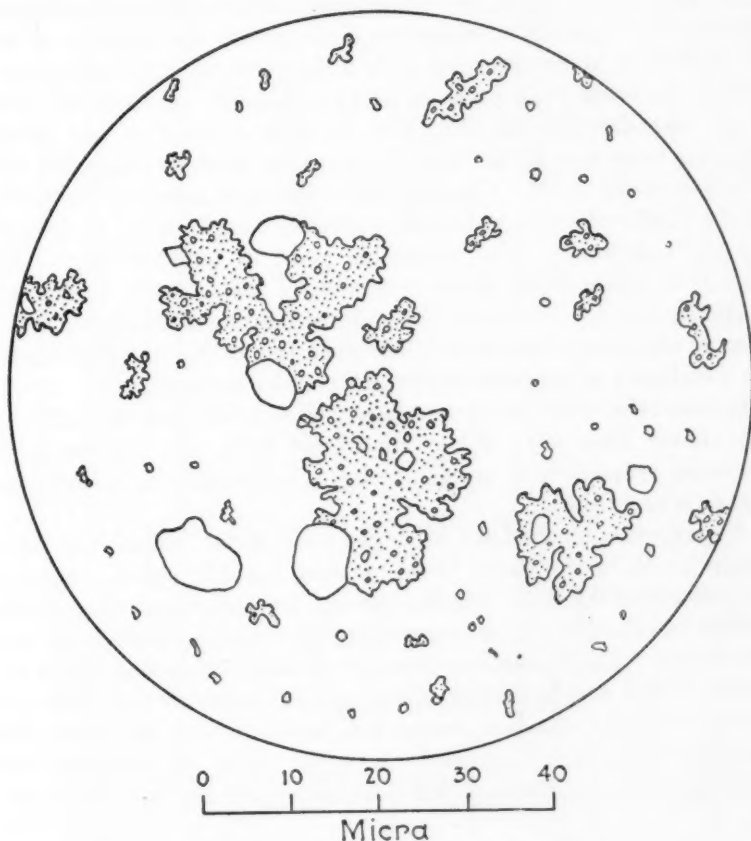


FIG. 1. CAMERA LUCIDA DRAWING OF SUSPENDED MATTER IN THE LAKE MICHIGAN WATER

The turbidity was 38 p.p.m., most of which was composed of partially coagulated masses of the finer particles. This is probably due to a supersaturation of some compound in the water such as silica or alumina.

and lime, or lime alone will clarify the water, but which of the methods will be the most economical for Chicago. Either of the three methods will remove the turbidity to the desired standard.

STANDARD FOR CLARITY

Several years ago the writer⁴ expressed the opinion that a properly coagulated water should filter to a turbidity of 0.2. This was based upon experiments using the Gunpowder River water at Baltimore. Plotting the quantity of coagulant used against the turbidity of the filter effluent, there appeared to be a sharp break in the curve indicating the economical point to be at a turbidity of about 0.2 (See Eng. News-Record, 92: 768, May 1, 1924). Later it was found that the break may be as low as 0.1 turbidity in many instances, but rarely ever above 0.2. Close attention has been given by the writer to the clarity of water which will not cause complaints or be noticed by the consumers. The noticeable point in bathtubs and other vessels of water likely to be observed by the average person is a turbidity of 0.5. To prevent frequent surpassing of this figure under normal operating conditions it has been found that the aim should be a turbidity of 0.2, with clarity alone under consideration. It was also found that there was better bacterial removal when the turbidity was lower than 0.5. When considered from the standpoint of bacterial removal it is usually desirable to reduce the turbidity as low as is practicable.

Experiments on the Lake Michigan water so far indicate this same sharp break in the curve to be between turbidity of 0.1 and 0.2. A turbidity of 0.2, after filtering through a standard sand bed, which will be described later, has been tentatively set as the desired standard for clarity. The theoretical quantity of coagulant is that which will produce this standard after filtration. All experimental work will be based on the standard, unless it is found at some later date that another figure should be used. In other words, no treatment will be regarded as satisfactory that does not reduce the turbidity to 0.2.

LABORATORY SAND FILTER

In 1924, the writer constructed a laboratory sand filter as shown in figure 2. The size of tube, thickness of glass, depth of sand, size of sand, etc., were decided upon after experimenting with various modifications. This was found to duplicate very well the large filter beds at the Baltimore filter plant. From the knowledge gained by conducting a large number of experiments in the laboratory, where

⁴ This Journal, 11: 824, July, 1924.

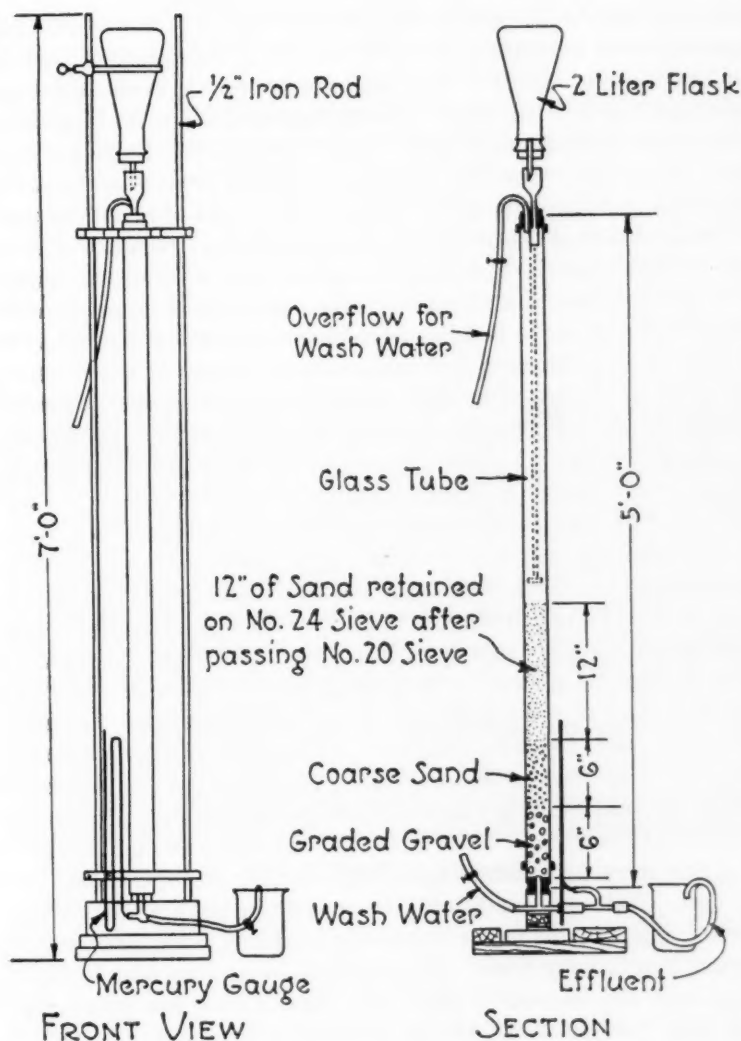


FIG. 2. LABORATORY SAND FILTER

the results could be checked on a plant scale, it was learned how to interpret the laboratory experiments very accurately. The bulk of the Chicago experiments will be made with such a filter.

An experimental plant with a capacity of about 500,000 gallons daily will be constructed in the early spring so that laboratory ex-

periments may be checked in an actual plant. For the number of experiments contemplated it would be out of the question both in cost and time to conduct them on so large a scale even as the experimental plant. Perhaps one surprising thing about the laboratory filter is the large size sand used (about 0.8 mm. for the 10 per cent size). Finer sand than this always gave better results than did the large beds at Baltimore, and it was not until sand of about 0.8 mm. size was tried that there was duplication of plant results. Taking into consideration the fact that the surface of a filter bed is usually never perfect, and that cracks or holes are usually formed in the surface layer after the bed has been in service for a few hours after washing, it is readily seen that reliance is not placed on the fine sand near the top of most filter beds for removing all of the suspended matter. In the experimental work it is planned to keep one laboratory sand filter with a standard sand, and to have one or more such units in which variations from the standard will be tried.

These filters may be adapted to almost any condition. They can be placed on the floor and all heads made positive, or they can be placed on a stand or table of any desired height, with the effluent tubes leading to the floor. In this way negative head may be introduced to the same extent as in a large filter plant. By raising the flask and funnel any head desired may be obtained. In this case the funnel is connected to the filter with a small glass or rubber tube. The filters may be placed in rooms of variable temperatures for testing the effect of temperature. They also may be connected to the influent of the large filters and comparisons made. The variety of conditions under which the laboratory filter may be operated gives an opportunity for conducting a large number of experiments at a low cost. Extreme conditions, frequently necessary for definite proof of some specific factor, are easily produced, whereas it may be impossible in a large filter. Many points on a curve may be established with the laboratory filter, and then with a few points on a large filter bed the trend of the curve for plant conditions may be predicted with considerable accuracy.

STIRRING MACHINE

The stirring machine shown in figure 3 is as important as the laboratory filter. The writer has used a similar machine for several years and finds it to be almost indispensable for studying coagulation. As agitation materially aids certain chemical reactions, it especially

applies to the formation of a coagulation in water treatment. Each stirrer of the machine has 2 blades, $\frac{1}{2}$ by $1\frac{1}{2}$ inches, fastened to the lower end of a $\frac{3}{8}$ inch brass rod which slides up and down in a hollow shaft so as to clear the top of the beakers. Two-liter beakers will be used for most of the experiments, although larger or smaller vessels may be used if desired. Adjustable rubber wheels drive the discs at the top of the shafts at any speed between 60 and 300 revolutions per minute. The time of stirring has great influence on the formation of the floc, which largely controls the rate at which it will settle in the settling basins. A rapid settling floc may be desirable for removing microorganisms by sedimentation so as to prevent

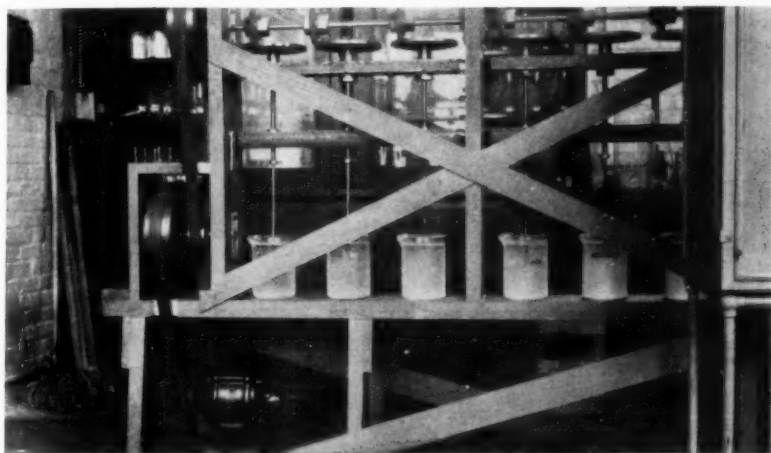


FIG. 3. STIRRING MACHINE

most of them from going on to the filter beds, and the effectiveness of coagulation in precipitating microorganisms can be studied thoroughly with the aid of the stirring machine.

At Baltimore, it was found that, with a certain time of stirring at a certain speed, the coagulation approximately duplicated that produced in the mixing basin. This proved to be advantageous in experimental work, for, with the laboratory filter, plant conditions could be duplicated in the laboratory. The laboratory stirrer and filter were used extensively at Baltimore in keeping the coagulant at a minimum. When the only means of telling if the coagulant may be reduced is to reduce it and run the risk of getting cloudy

water through the filters, the operator naturally hesitates to reduce unless it is evident that considerable excess is being added. The day is approaching when methods now in use for determining the quantity of coagulant to apply in a filter plant will be regarded as crude and wasteful of chemicals.

After the experimental plant in Chicago is constructed and in operation, its efficiency will be checked with the laboratory apparatus. If it is found that there is considerable difference in the results obtained it may be desirable to change or extend certain parts of the experimental plant. The plant is being designed with greater flexibility than has ever before been attempted for an experimental plant.

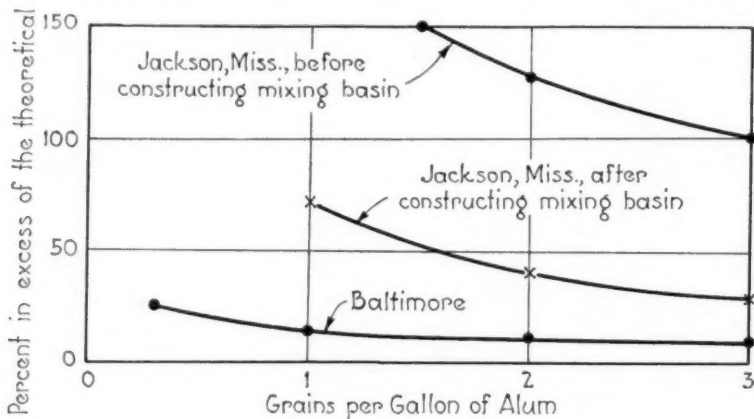


FIG. 4. EXCESS OF ALUM IN PLANT OPERATION OVER THE THEORETICAL QUANTITY NECESSARY TO CLARIFY THE WATER

It is hoped that the laboratory results can be duplicated with considerable accuracy. The minimum quantity of chemicals necessary to clarify and perhaps to soften the water will be determined in the laboratory with the stirring apparatus and the laboratory filter. This will require operating the experimental plant under extreme conditions for part of the experiments, conditions that are known not to be economical for a large plant, but it is only from such information that the most economical layout of the large plant may be determined.

Should it take only 0.2 of a grain per gallon of alum to clarify a turbidity of 20 in the laboratory and 0.4 in a filter plant, it would be evident that the layout of the plant was not efficient. Some plants

show considerable difference between the theoretical, as determined by the laboratory apparatus, and the actual amount used. A great many plants have been designed only to produce clear water and no one has any idea whether the layout is efficient or not. What is now needed in filtration practice is a procedure for accurately determining in the laboratory the minimum quantity of coagulant necessary to produce the desired clarity and bacterial removal for a given water. When plant results deviate greatly from the theoretical an effort should be made to improve conditions.

These facts are illustrated in figure 4. The mixing basin at Baltimore, which has a period of nearly thirty minutes mixing at rated capacity, is believed to be an efficient basin for aluminum sulfate. The excess of alum in plant operation required over the minimum, as determined with the laboratory stirrer and filter, varies from about 25 per cent for 0.3 grain per gallon to about 10 per cent for 3.0 grains. In this case the laboratory samples were stirred for forty-five minutes. The excess is in addition to about 10 per cent always allowed for fluctuations in the strength of the alum solution and in the controlling apparatus. A longer mixing period in the plant at Baltimore may reduce the excess slightly, but the mixing basin as now constructed approaches the economical limit. Perhaps it should be mentioned that the basin was designed for the use of iron and lime and was made for a longer period of mixing than is usually considered necessary for alum. Compare this with the alum used in the filter plant at Jackson, Miss., in 1915 and 1916.⁵ This plant was originally constructed with little mixing, but a small mixing basin was added in 1916. The curves for Jackson are only approximate, for the writer stirred the samples by hand, filtered through paper, and had no accurate turbidimeter. The results, however, are not far from correct. The addition of a short mixing basin reduced the amount of alum materially, but it was still a considerable distance from the theoretical.

COAGULATING WITH ALUMINUM SULFATE

The Lake Michigan water is easily coagulated with aluminum sulfate. The reason for this has not as yet been definitely determined, but, as stated, there are indications that the water is already saturated with soluble alumina and the addition of any amount of

⁵ Baylis, Eng. News-Record, 80: 364, February 21, 1918.

alum, however small, produces a precipitate. It is also probable that the nature of the suspended matter has considerable influence. Since most of the rain water in the vicinity of Chicago is discharged through the Chicago River and the Drainage Canal to the Illinois River, there is not much fine suspended matter entering the lake at this point. Turbid water from wave action near the shore is constantly being taken out of the lake through the canal. Most of the turbidity in the section near the intakes is caused by wave action picking up the suspended matter precipitated at some previous time. Samples of the turbid lake water stored in bottles usually coagulate

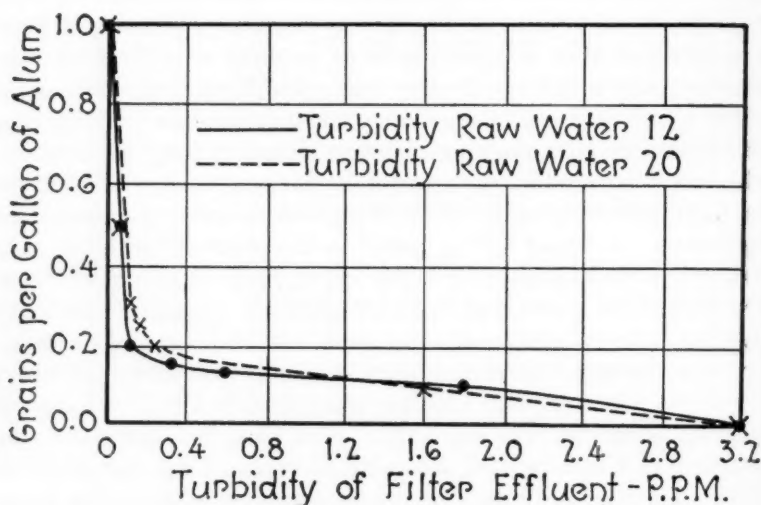


FIG. 5. CLARIFICATION PRODUCED BY VARIABLE QUANTITIES OF ALUM; THIRTY MINUTES STIRRING

and settle to a turbidity of less than 5 within twenty-four hours; that is, the small coagulated masses shown in figure 1 have a tendency to unite into larger particles which are approximately the size of aluminum hydroxide floc. The suspended matter since the experiments were started appears to be composed of a turbidity of 3 to 10 parts of fine suspended matter and the balance is in masses of partially coagulated particles. It is likely that the amount of fine turbidity, which most of the time has ranged near the lower figure, largely determines the amount of alum necessary to clarify the water.

The curves in figure 5 are about the average of conditions for fairly

low-turbidity water. This is after filtering through the laboratory sand filter which had sand that was retained on a No. 30 sieve after passing a No. 20. Two-tenths of a grain per gallon of alum at the time the experiments were made appears to be approximately the theoretical amount for clarifying the water to a turbidity of 0.2. This is probably much less alum than is being used in most plants filtering the Great Lakes water to this clarity. It is also less than would be necessary for a large plant in Chicago. The economical layout of a well designed plant should not exceed the theoretical by more than about 25 or 30 per cent; that is, when the theoretical amount is 0.2 grain per gallon, a large plant should use somewhere between 0.25 and 0.3 grain.

The above applies to the coagulant necessary only to clarify the water. During periods when microorganisms are in abundance, it may be found advisable to use more coagulant so as to precipitate a large percentage of the organisms in the settling basins. Treatment with aluminum sulfate would make the water slightly more corrosive, but not to an objectionable extent. The sulfate hardness would also be increased in proportion to the alum used, but there would be no change in the total hardness. If microorganisms were not a factor and there was nothing to be gained by softening, there would be little doubt about alum being the most economical chemical to use. The ease, however, with which some of the hardness may be removed from the water is a factor well worth considering.

IRON AND LIME

The lake water responds readily to treatment with iron and lime in the laboratory and, due to the softening effect, this treatment may prove to be very economical. The curve in figure 6 shows what may be accomplished with variable quantities of iron when 2 grains per gallon of lime (CaO) are used. A very good coagulation can be obtained with iron when any quantity of lime in excess of about 0.5 grain is used. The economical amount of lime will depend on its softening value. The reduction in hardness is fairly rapid for small quantities of lime and it certainly would be desirable to use at least 2 grains. Experiments indicate that the hardness will be reduced at least 35 parts per million with this amount, which is a reduction of about one grain of hardness per grain of lime used. Certainly this reduction is well worth while.

It may be desirable to use more than 2 grains of lime, but this is

getting near the point where it would be necessary to carbonate the water in order to produce a satisfactory product. The upward trend in the total hardness as the amount of iron used is increased, shown in figure 6, indicates that it is desirable to have very efficient coagulation. This will require considerable attention to the design of the mixing basin. Mr. C. Arthur Brown has always been an

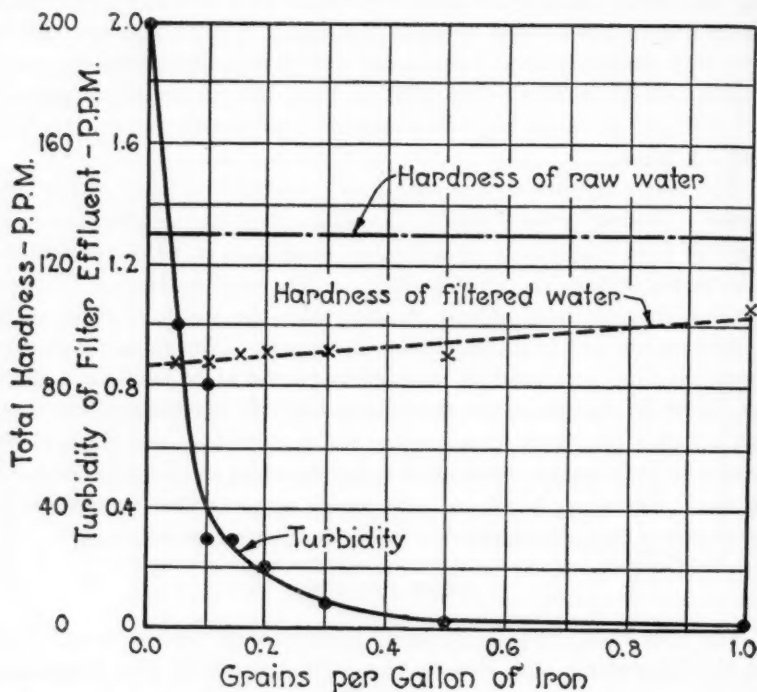


FIG. 6. CLARIFICATION PRODUCED BY VARIABLE QUANTITIES OF IRON, 2 G.P.G. LIME (CaO), STIRRED THIRTY MINUTES, TURBIDITY
RAW WATER, 12 P.P.M.

advocate of prolonged mixing, together with a certain violence of the agitation to produce the best results with iron. The writer agrees with Mr. Brown.

LIME FOR SOFTENING AND CLARIFICATION

The excess lime treatment is now being used for certain hard waters where it is desirable to soften for boiler uses. This leaves the water

with some caustic alkalinity, and it is not satisfactory for domestic supplies unless the caustic alkali is changed to the carbonate or bicarbonate. Within the past few years recarbonating highly alkaline waters has been demonstrated to be a success for municipal supplies, probably being tried out first at Defiance, Ohio.⁶ This opens up a new field in the softening of certain hard waters. Mr. C. P. Hoover of Columbus, Ohio, perhaps has done more than any one else in contributing to our knowledge of the softening of municipal water supplies, and much of the success in extending the excess lime treatment and recarbonization to municipal supplies has been due to his efforts.

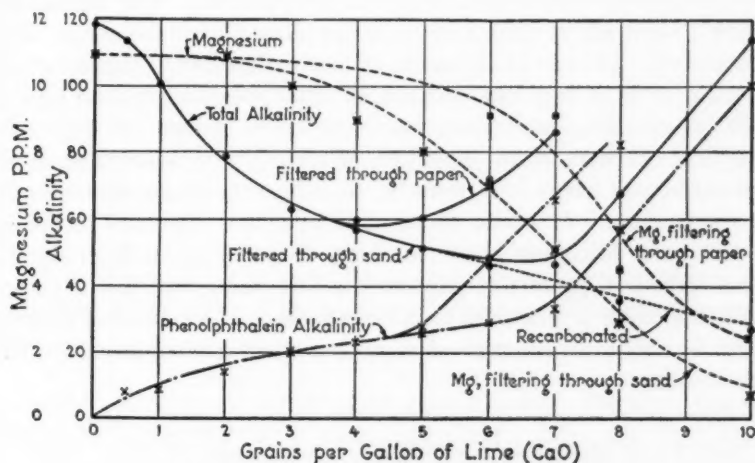


FIG. 7. RESULTS OF TREATMENT WITH LIME

The Lake Michigan water has a total hardness of about 130 parts per million, nearly all of which is carbonate hardness. This is not very hard and is at the point where it is doubtful if the excess lime treatment would be economical. The lake water is always near the equilibrium point of calcium carbonate and the addition of any quantity of lime in excess of about 0.2 grain per gallon forms some calcium carbonate precipitate and leaves the water softer after filtration than before treatment. The addition of lime up to about 3 grains (pure CaO) softens at approximately the rate of one grain of hardness per grain of lime, but beyond this point the rate drops

⁶ Hill, This Journal, 7: 440, July, 1920.

off. Recarbonization is essential either before or after filtration when over 2 grains of lime are used, and this will hold up to the point where caustic alkalinity starts. Beyond this the caustic alkalinity at least should be carbonated before filtration and the filter effluent should then be carbonated to nearly the solubility equilibrium of calcium carbonate.

When about 6 grains of lime are added, magnesium hydrate begins to precipitate in quantities that will coagulate the suspended matter in the water. The precipitate formed is heavy and settles rapidly. The water then, after recarbonating, will filter perfectly clear. With less than about 5 grains of lime a coagulant for removing the suspended matter probably will be essential. The curves in figure 7 show about what may be accomplished with the excess lime treatment. The use of 10 grains of lime reduces the magnesium to about 3 parts of Mg, but it is evident that recarbonating so high a caustic alkalinity is beyond the economical point for domestic supplies. It does show, however, what may be accomplished in industrial uses where it is desirable to reduce the magnesium as well as the calcium. It would be possible to reduce the total hardness of the Lake Michigan water to about 40 parts per million should some industrial process require such a soft water, but this is somewhat less than is practical on a large scale. The following experiment is about an average of what has been accomplished in the laboratory:

Raw water

Turbidity 10, alkalinity 118, pH 8.0, total hardness 130.

Treated with 10 grains per gallon of lime (pure CaO), stirred twenty-five minutes in the stirring machine, and decanted after settling thirty minutes. About 95 per cent of the precipitate settled out.

Filtering through paper the phenolphthalein alkalinity was 120 and the methyl orange alkalinity 130.

The sample was carbonated, allowed to stand one hour, and then filtered through the laboratory sand filter.

Filtered water

Turbidity 0.00, phenolphthalein alkalinity 10, methyl orange alkalinity 27, soap hardness 36, calcium (Ca) 9.9, magnesium (Mg) 3.3, total hardness by computation from the amount of magnesium and calcium present 39.3.

Should the excess lime treatment prove to be desirable for Chicago, about 6 grains of lime would be the most desirable quantity to use. By settling out the heavy precipitate in a small settling basin and

carbonating the caustic alkalinity before passing the water through fairly large settling basins, the total hardness may be reduced to about 50 parts per million in a large size plant. In this case probably one-third of the magnesium would be removed, which would leave the calcium-magnesium ratio somewhat out of the proportions usually found in natural waters, but this probably would be of little consequence. The excess lime treatment would solve filter clogging troubles from microorganisms, would produce a clear and palatable water, and the treatment is generally thought to have considerable sterilizing value. The sulfate hardness would not be increased, if lime reasonably free from SO_3 is used. The chief advantage of the treatment is reducing the hardness to such a low point, but the cost of construction and operation may be so great that a partially softened water would be more economical.

The writer wishes to express his appreciation of the valuable suggestions made by Frank Hannan of Toronto on the possibilities of the excess lime treatment for clarifying and softening the Great Lakes water.

DISCUSSION

W. R. GELSTON: When we tried excess lime treatment at Quincy there was trouble with clogging of sand beds and filling of pipes with lime.

JOHN R. BAYLIS: It is best to carbonate before filtering. Otherwise some of the softening takes place after passing the filter bed.

W. R. GELSTON: We had only one hour of sedimentation at Quincy.

C. P. HOOVER: The author is to be congratulated upon the paper. The use of excess lime together with carbonation is a new method of procedure in softening. It is possible to make the water so clear and the load on the filters so light that the filters might be run at three times the ordinary rate of filtration.

G. C. HABERMEYER: Filtering at rates of 4 or 5 gallons per square foot per minute would make friction losses high.

W. LUSCOMBE: Have you considered extending intakes further into the lake instead of filtering?

JOHN R. BAYLIS: To get water fairly free from turbidity we must get the water at a depth of 40 to 50 feet and that would require intakes ten miles farther from shore. During a recent investigation we found that turbidity extends from shore to distances of 12 to 14 miles after storms, and that microorganisms were high. Three or four cyclops per liter were found 12 miles from shore.

A. M. BUSWELL: Have you made studies concerning the disposal of sludge? Lime treatment of sewage sludge has been found beneficial.

A. V. GRAF: At Detroit 6 million gallons per day are filtered through beds designed for 4 millions. Sand grains became encrusted. Cyclops are more frequent at great depths. At St. Louis there have been so many at the bottom of 35 foot basins that the sludge on the bottom has been kicked up to make clouds of turbidity.

FLOOD CONTROL IN THE MIAMI VALLEY OF OHIO¹

BY C. S. BENNETT²

The Miami River drains the southwestern portion of the State of Ohio. Its source is in Logan County just west of the center of the state, and it empties into the Ohio River at Cleves, a few miles below Hamilton. The total length of its winding course is 163 miles. The important tributaries of the Miami above Hamilton are Four Mile, Seven Mile, Twin, and Wolf Creeks, the Stillwater River and Loramie Creek from the west, and Mad River from the east. Wolf Creek and Stillwater and Mad Rivers join the Miami in the City of Dayton. The Miami drainage area is about 120 miles long. Its area above Hamilton is 3672 square miles and above Dayton, 2600 square miles. The slopes are short and steep, the grades of the main streams rather flat. While draining of swamp lands, tiling, cultivation of farms, and possibly the destruction of the forests have slightly increased the flood runoff, the tremendous floods that sweep down the valley are due primarily to the great storms which occur at intervals in this section of the United States.

First settled about 1790, the Miami Valley has grown to be a prosperous community with numerous busy towns and rich farm lands. The towns have, in general, grown up along the streams and the old Miami and Erie Canal, which were the first means of transportation, and consequently these towns are in the overflow channel of the river in many cases. The history of the valley is replete with accounts of serious floods, culminating in the great disaster of 1913. In the past, more or less inadequate levees had been built around the towns, but until after the flood of 1913, no comprehensive plan for making the valley safe had ever been adopted.

THE 1913 FLOOD

A tremendous storm swept the Miami Valley from March 23 to 27, 1913. It caused the most severe flood that had ever been known in

¹ Presented before the Indiana Section meeting, February 8, 1927.

² Engineer, The Miami Conservancy District, Dayton, Ohio.

that valley,—in fact, the greatest flood, as regards damage, that has yet occurred in the eastern half of the United States. For five days the rain continued; the total precipitation averaged around 10 inches over the watershed above Dayton. The ground was saturated and partly frozen, so that the runoff from this great rainfall was very considerable,—practically 100 per cent during the latter part of the storm.

In the building of cities, railroads, and bridges, and in locating improvements near rivers, the usual high-water stages are taken into account. It has frequently been assumed that past floods, with perhaps a little estimated increase, are a reliable criterion of what may happen in the future. The fallacy of this reasoning for districts where records are available only over short periods, was well illustrated in the Miami Valley during the flood of 1913. Levees and bridges had been built there to accommodate the largest flood that had occurred during the forty years or so that records were available. The water in Dayton during the crest of the 1913 flood stood about six feet higher than the tops of those levees. Not a bridge across the river was passable, many of them were washed out entirely. Nearly four times as much water came down the river as the leveed channel could carry. Large parts of the business and residential districts of the city were overflowed to depths up to twelve feet. Similar conditions existed in the other cities and towns throughout the valley.

Thousands of people were marooned for three days and nights in the attics and on the roofs of their dwellings. Over 400 lives were lost. Property loss has been estimated at about \$100,000,000, not including the indirect losses, such as interruption of business, loss of time, depreciation in property values, illness to many people as a result of exposure and shock. Fires added to the destruction in Dayton and Hamilton. Many bridges were wholly or partially destroyed; great areas of street paving were damaged or entirely washed away; mud and silt were deposited in layers in houses, offices and factories; transportation facilities were entirely disrupted. The communities of the valley were prostrated by the calamity.

ORGANIZATION FOR FLOOD CONTROL

The flood waters had hardly subsided before relief committees were organized in the different cities of the valley. At first the work of the committees was confined to emergency help to the flood sufferers, but within sixty days after the disaster, and while the people were still

overwhelmed with the problems of their personal losses, the citizens of Dayton alone raised a fund of \$2,000,000 for the purpose of making the necessary surveys and studies to work out a flood prevention program. More than 23,000 individuals contributed to this fund.

At first each community in the valley approached the problem independently, the thought being that protection could be secured by channel improvement and levee construction through each city. As the investigations progressed it became apparent that the difficulties in securing a satisfactory solution to the big problem were so great that the individual communities could not meet them separately, and that coöperative action of the entire valley was necessary.

The investigations of the engineers indicated that channel improvement alone was impracticable, and the next thought was for retarding basins. Further considerations brought the conclusion that a combination retarding basin—channel improvement plan would best meet the situation, and the project was worked out through the co-operation of all of the communities in the valley in one comprehensive plan.

Under the Ohio laws there was no practical way for the people to organize for this particular purpose, and it became necessary therefore to enact legislation which would provide for such organization. The Conservancy Act of Ohio, passed in 1914, was the result of this effort. Through the provisions of this law a community may, by petition, organize a District for flood control purposes. Provisions are made for the necessary preliminary investigations, submission and adoption of a plan, appraisal of properties affected, levying of assessments for carrying out the plan, issuance and sale of bonds to provide immediate funds, and other steps necessary for the construction and maintenance of the works of the District. Figure 1 indicates the sequence of steps preliminary to the construction of a flood control project. The arrows in each case start at the party taking the action and point to the party with whom the action is taken. For example, beginning at the upper left hand portion of the diagram and following the first two arrows from left to right, it will be seen that action under the law is started by the property owners filing a petition and bond with the Court. Following the third arrow from right to left, it appears that the Court then publishes notice of a hearing on the petition. Next the property owners may file objections with the Court to the organization of the District, as indicated by the fourth arrow, and so on.

The fundamental principles involved in the law are few and simple. The Court of Common Pleas exercises the primary functions in the proceeding. The Directors, who are appointed by the Court and act as the business managers of the District, handle all of the details of the organization and construction of the works. The appraisers are appointed by the Court. Their job is to make an appraisal of all

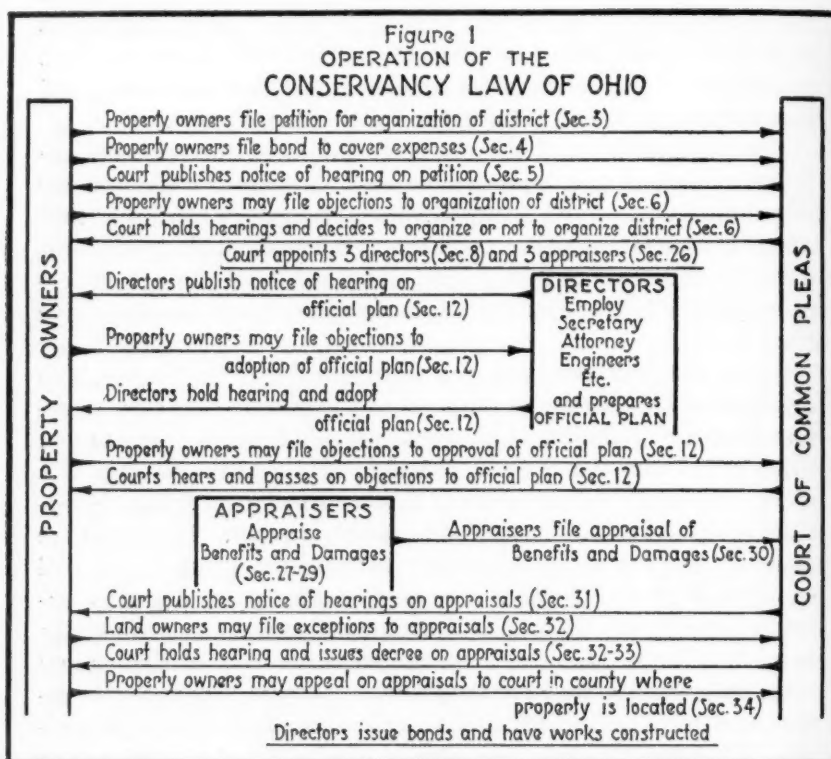


FIG. 1

benefits and damages to property affected by the proposed construction, and it is upon their appraisal of benefits that the assessments for construction and maintenance purposes are based. All expenses incidental to the carrying out of the program of a District are met by a direct levy on the properties and communities actually benefited by the work. In anticipation of the collection of these assessments, bonds may be issued to provide immediate funds.

THE DEVELOPMENT OF THE PLAN

The Miami Conservancy District was established by the Court in June, 1915. During the time that elapsed while the legislation was being worked out and finally passed, the engineers employed by the citizens had completed their studies and investigations to the point where a complete plan could be outlined. Fortunately, the engineers were called in shortly after the flood, when high-water marks and other desirable records were still available. The great quantity of data collected included typical cross-sections of old channels; levee profiles; cross-sections of the valleys at controlling points; surface slopes during the peak of the flood; size of bridge openings; time of flood crest at different places; velocity of flood flow; rainfall and runoff data; information on past floods in the Miami Valley and elsewhere; topographic surveys.

As soon as sufficient data had been obtained, studies and computations were made. These included studies of flow in open channels; determination of the value of "n" in Kutter's formula, under various conditions; computations of peak flow and total discharge, at various points, during the 1913 flood; study of shape, size and character of the drainage area; determination of the maximum possible flood; study and investigation of various methods of flood control; estimates of costs of various flood control plans. As soon as the retarding basin scheme became a possibility, other questions presented themselves, among the more important of which were the determination of the location, size and number of dams; tentative channel capacities through the cities; determination of height of dams and size of conduits; backwater effects and curves; spillway capacities; balancing of retarding basin capacities, outlet capacities and channel capacities; and finally, a determination of public and private property affected; valuations of properties as to damages and benefits; preliminary estimates of cost.

The so-called "Official Plan," which indicated the exact methods to be used in securing the necessary flood protection, together with the volume and character of work required, types of structures and estimates of cost, was presented to the Court by the Board of Directors of the District, and was approved by the Court late in 1916.

Meanwhile the three appraisers appointed by the Court began to determine for all real property and for the communities as a whole, the benefits which result from the construction of protection works.

About one half of the total benefits was assessed to the cities and counties as a whole. These are in proportion to the degree that a flood equal to that of 1913 would affect them as communities. The other half of the benefits was assessed to the individual pieces of property subject to actual flooding. The value of the property, degree of protection needed and provided, depth of flooding in the 1913 flood, were all taken into consideration in assessing the benefits. For example, a property subject to flooding ten feet deep was assessed a larger percentage of its value than one subject to only three-foot flooding. That is to say, each property was assessed in accordance with the degree of benefit to be received. There were about 70,000 pieces of property affected. When the benefits were added up they totalled about \$77,000,000.

The construction was paid for from the proceeds of the sale of \$33,890,909.83 worth of bonds, secured by the benefits appraised and representing approximately 45 per cent of the total benefits. The bonds will be retired by 1949, a portion being taken up each year. The money to take up the bonds, to pay the interest on the bonds, and to pay for the maintenance of the works, is provided by a tax against the benefited property. Since about one-half of the total benefits was assessed against the cities and counties of the District, about one-half of the yearly tax is levied against all of the property in the cities and counties. The other half is levied against the properties protected against actual flooding in proportion to their benefits.

In addition to the establishment of the benefits, the damages caused by the proposed works were set by the appraisal board. Rights of way were obtained, and the rights to flood the lands in the retarding basins were secured. As these lands are still available for agriculture, a portion of the land owners elected to sell a flood easement to the District. Others, uncertain as to the effect of the basins on their property, sold their holdings outright to the District. About 30,000 acres were so purchased. These lands are being resold with a flood easement attached.

DESCRIPTION OF PROJECT

The map of the District (fig. 2) shows the principal features of the flood control project. Before the "Official Plan" was adopted many schemes had been studied and discarded as not practical, or as too expensive. The diversion of Mad River into the Little Miami, the building of by-passes for carrying the water around the cities, channel

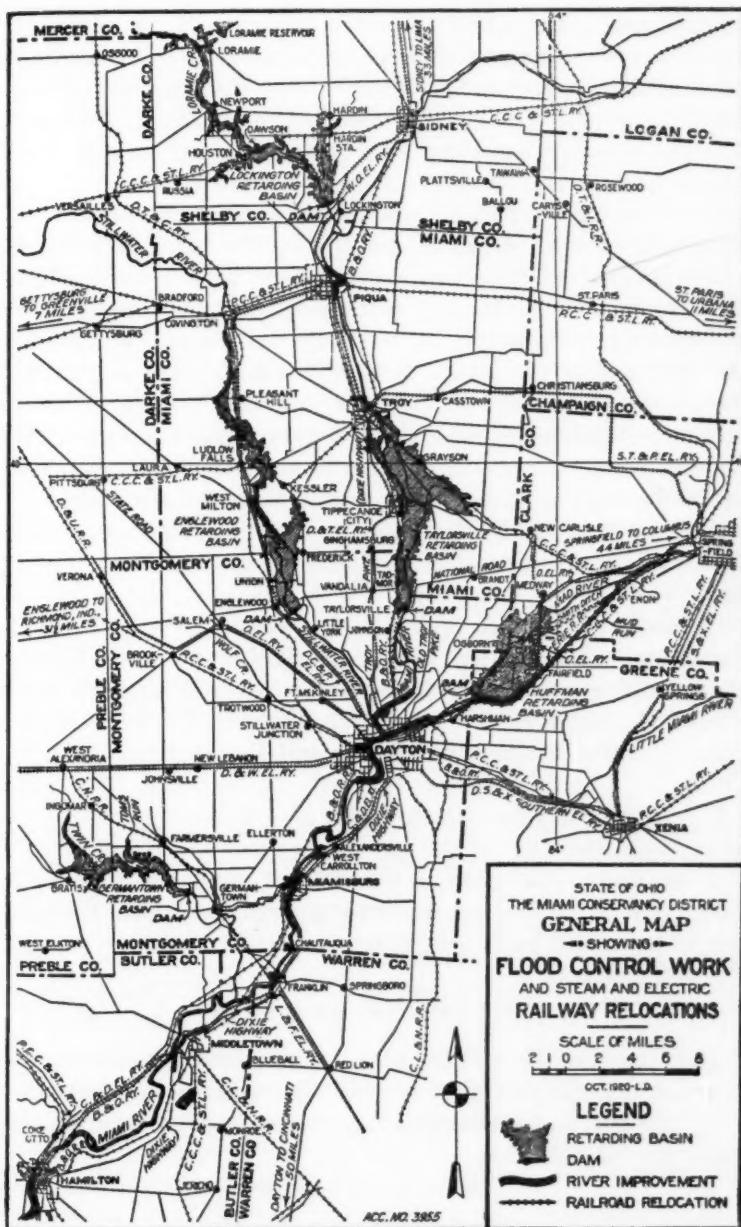


FIG. 2

improvement alone, and a system of many small retarding basins, were among the schemes that were found undesirable. After the present retarding basin—channel improvement plan was decided upon, much thought was given to the possibility of combining flood prevention and power development, but it was not found possible or practicable to make this combination in the Miami Valley.

The flood control plan provides for channel improvement through all the cities and towns affected by floods to the extent that is economically feasible, supplemented by retarding basins which will hold back the crest of the flood by restricting the flow through the dams and backing up the surplus water temporarily in the basins. There are no gates in the outlet structures through the dams. These structures are designed of such size that their combined discharge under maximum head (full basin) will not overtax the capacity of the improved river channels through the cities below. Provision is made to handle a flood 40 per cent greater than the 1913 flood. The studies and computations indicated that a flood 20 per cent greater than that of 1913 probably would be the greatest that might occur in the valley.

Channel improvement is provided at Piqua, Troy, Dayton, West Carrollton, Miamisburg, Franklin, Middletown and Hamilton. Dams forming retarding basins are located at Lockington on Loramie Creek; at Englewood on Stillwater River; at Taylorsville on the Miami; at Huffman on Mad River; and at Germantown on Twin Creek.

It was necessary to relocate about fifty miles of railroad lines in order to get them out of the way of the dams and retarding basins. New locations satisfactory to the railroad companies were made at the expense of the District, under the general direction of the railroad companies. This work cost about \$5,000,000, exclusive of right of way and damages.

CONSTRUCTION OF PROJECT

All of the work, except the railroad relocations, was done by a construction organization built up and equipped by the District.

The quantities of materials involved were large; some of the major items are as follows:

Public service relocations

- 2,500,000 cubic yards excavation.
- 30,000 cubic yards concrete.
- 55 miles railroad track.

Flood prevention works

- 8,200,000 cubic yards embankment in dams.
- 2,550,000 cubic yards embankment in levees.
- 5,330,000 cubic yards excavation in river channels.
- 162,500 cubic yards concrete in outlet works at dams.
- 89,000 cubic yards concrete in walls and levee revetment.

Channel improvement. The combination of channel improvement and retarding basin control permitted the channel enlargement to be confined to moderate limits through most of the cities. The standard channel cross-section has a low-water section about 150 feet wide, with flat slopes or beaches on either side extending out to the toes of the levees. The low-water channel is located in the center where the river is straight and near the outside of the bends where the channel is curved. The side slopes of the levees are 2 to 1, and where neces-

TABLE 1
Principal dimensions of dams

	GERMAN-TOWN DAM	ENGLE-WOOD DAM	LOCK-INGTON DAM	TAYLORS-VILLE DAM	HUFFMAN DAM
Volume earthwork, cubic yards.	800,000	3,600,000	970,000	1,130,000	1,350,000
Maximum height, feet.....	110	125	78	78	73
Length, feet.....	1,200	4,700	6,400	3,000	3,300
Maximum thickness at base, feet	665	785	415	415	380
Volume concrete work, cubic yards	17,400	26,500	32,000	48,000	37,500

sary because of high velocities, the slopes are paved with concrete. Where conditions demanded, the levees are supplanted by retaining walls.

Dragline excavators were used almost exclusively to handle the channel excavation and levee construction. They were also used for the excavation work at the dams. On the various jobs, twenty-one of these machines were used, varying in size from the small machine having a 30-foot boom and $\frac{3}{4}$ -yard bucket to the large electric machines with 100-foot boom and 5-yard buckets.

In many places the dragline machines placed the material excavated from the channel directly into the levees. Sometimes two or three throws were necessary to get the material into the levees. At Dayton and Hamilton, where the excavation far exceeded the amount needed for levee construction, provision had to be made for wasting

the excess material. This was accomplished at Hamilton by hauling the material out in trains of 12-yard dump cars to several spoil banks. At Dayton, on a large part of the work, it was not possible to lay tracks in the river bed, and the excess material was loaded on to scows which were towed to the spoil bank areas by a small steamboat.

At the cities where the principal improvement was levee construction, the work was done usually by dragline machines which excavated from adjacent borrow pits.

The dams. All of the five dams are of earth, built by the hydraulic fill method, and pierced by concrete conduits which carry the normal stream flow through the embankment.

The principal dimensions of the dams are given in table 1.

Construction camps were built at each dam site to take care of the required number of employees and their families, as there were no towns close enough to any of the dams to provide the necessary accommodation. These camps were made as comfortable and up-to-date as possible.

The first major construction job at each dam was building of the concrete outlet structure. These are of two types. At the higher dams,—Englewood and Germantown,—they consist of twin culverts or conduits passing entirely through the dam in the stream channel. The spillways at these dams are separate structures. At the three other dams, combination outlet and spillway structures were erected. All of these outlets were constructed on bed-rock foundations.

At the downstream end of each outlet structure a stilling pool was built for the purpose of dissipating the energy of the swiftly flowing water. This structure is so designed that the hydraulic jump or standing wave is formed within the limits of the concrete structure, and the floor and walls are made of sufficient thickness to withstand the action. The velocity is thus reduced, before it leaves the structure, to an extent that it will not erode the unlined channel below.

Construction of the dam embankments was handled as far as possible by hydraulic methods entirely. At most places the borrow pit material lay too low to be directly sluiced to the dams. The material was either sluiced from the borrow pits by hydraulic giants and then picked up by dredge pumps and conveyed to the dams through pipe lines, or was excavated by dragline machines, loaded on cars and hauled to the pumps near the toe of the dam and then pumped into place. Regardless of how the material was brought to the dredge pumps, the process from there on was practically the same at all of the

dams. The hydraulic fill process automatically breaks up the borrow pit material into its component parts and distributes the material in the dam in such manner that the coarse material is left in the outer portion of the dam, forming stable outer slopes, and the fine material is concentrated in the center where it settles through a central pool or "core pool" to form an impervious core.

Progress and cost. Construction work began during the season of 1918. The intention was to push the work with all possible speed consistent with economy, because flood protection for the valley was of vital importance. All the larger jobs were started at once, and as far as practicable all work was carried on by two ten-hour shifts.

The rate of progress made varied with the equipment used. At Germantown, with one dragline machine in the borrow pit, and one dredge pump, an average month's work was 60,000 to 70,000 cubic yards, while the largest month's work was 91,500 cubic yards. At Taylorsville, with four giants in the borrow pits, and two dredge pumps, the highest monthly output was 107,000 cubic yards. At Englewood, with three dragline machines in the borrow pits, and two dredge pumps, the monthly record of hydraulic fill often reached 150,000 cubic yards, and during one month it amounted to 180,000 cubic yards.

By the middle of 1921 the work was in such shape that a repetition of the 1913 flood would cause only a limited amount of damage, and by the end of 1922 the work was ready to handle any flood that might occur.

The total cost of the project was about \$30,000,000, of which approximately \$24,500,000 was expended on construction and the balance for lands, damages, and other expenses. A considerable amount of the farm lands in the retarding basins is being sold, subject to flooding easements, and the land investment is thus being reduced.

MAINTENANCE ORGANIZATION

As soon as the construction of the works of the District was completed, a permanent maintenance organization was perfected and a definite program for the proper and necessary care of the works was mapped out. A headquarters office is maintained at Dayton in a building constructed for the purpose. The offices of the Chief Engineer and his assistants, the clerical and accounting force, the farm department and the tax department are located in this building. A

central garage is also maintained at Dayton to care for the cars and trucks needed.

In each of the cities and towns where there are local protection works and at each of the five dams, resident caretakers are employed. These men, with help when necessary, patrol the levees and dams, remove debris, cut brush and weeds, look after the gates on the numerous sewers which extend through the levees, make daily readings of the river stage and rainfall and perform such other work as may be necessary.

Careful and continuous attention is given to all of the works and properties of the District. Any proposed structures, such as bridges and dams, or other construction, such as pipe lines or wire lines, which are contemplated by private or public interests and which in any way affect the works or property of the District, must be approved by the Chief Engineer. Special attention is given to the design of bridges over the streams to see that ample clearances are provided for maximum flows.

Measurements are made of the flow during high stages of the streams and of the flow through the dams in order to obtain actual data on the operation of the works.

OPERATION OF THE PROJECT

It was not long after the completion of the works of the District that they received their first real test, and the result was an excellent demonstration of the workings of the flood protection system.

On April 11, 1922, a severe storm started which culminated on the 14th with very heavy showers. The rain poured in torrents all of that afternoon and then continued with lessened severity well into the night. This rain was general throughout the valley. An inch and a half fell in less than two hours in many places. The total rainfall for twenty-four hours, from midnight of the 13th to midnight of the 14th, was three and one half inches, and this fell on saturated ground.

Under the old conditions a flood stage of 18 feet in Dayton, the old danger mark, would have been exceeded, and a bad flood scare would have resulted. Actually, however, the river only reached a maximum stage of 9.6 feet in Dayton. About one-half of the reduction in gauge height was due to river channel improvements and the other half was due to the holding back of water behind the dams. All of the basins stored water, the maximum depth of backwater on the conduit floor

at Germantown Dam being 40 feet, at Englewood Dam 37 feet, and lesser amounts at the other three dams.

Only 32 per cent of the channel capacity at Dayton was used, and only 4 per cent of the basin storage capacity was utilized. The storm had reached the stage where, had it continued, the rise in the river would have been relatively much slower, as the basins were holding back more and more of the runoff and were just really beginning to store any amount of water.

Everything worked out according to plan. The water was carried through the improved river channels in the cities smoothly and swiftly, the familiar turbulent appearance in former floods being entirely absent. At all of the dams the hydraulic jump worked just as expected and only a few hundred feet below each of the outlets the water was flowing smoothly. Practically no damage was done to property in the valley or to the works of the District.

There was intense interest by the public in the working of the system and it was necessary to place traffic men at the Englewood Dam to keep the crowds moving. The storms of April, 1922, were widespread and many communities suffered loss of life and property due to floods, but the citizens of the Miami Valley viewed their own situation with complacency. Less than one hundred telephone calls about the river stage were received at the Conservancy office as compared with nearly two thousand during the high water of 1920.

Since 1922 there have been several severe storms, and in each instance the flood control works functioned as planned and no damage resulted. On June 8, 1924, a near-cloudburst caused a rainfall of over $4\frac{1}{2}$ inches in a few hours over the upper part of the Stillwater River watershed. The resulting flood of water caused a very rapid rise of the Stillwater River and its tributaries, but the Englewood Dam effectually checked the flow and the river at Dayton reached only the moderate stage of 13 feet. The maximum depth of the backwater at Englewood Dam was 52 feet, and the temporary lake covered an area of about 2300 acres.

From April, 1922, to January, 1927, there were four storms which would have caused considerable damage from flooding in the valley had the control works not been constructed. Excess water was stored behind the Germantown Dam on 35 occasions, and at Englewood 25 times, in the period referred to.

USE OF TWO WATER MAINS IN WIDE STREETS¹

BY THOMAS F. WOLFE²

In the days, not long ago, when horse-drawn vehicles furnished the means of transportation and haulage, the narrow streets we find in the older sections of our big cities were ample for the traffic they were called upon to carry. The number of vehicles was few as compared to what we now have and the speed was limited. The introduction of the automobile changed these conditions. Streets that formerly took care of a few slow moving vehicles are now required to handle large numbers of fast moving automobiles. The net result is that where streets as narrow as 30 feet were once fairly common, we now find streets from 80 to 200 feet in width with roadways all the way from 40 to 80 feet. In addition to affecting the width of roadways, the automobile has influenced the design of the pavement. During the days of horse-drawn vehicles, wheel loads were necessarily limited by the capacity of the horse, whereas our modern motor trucks, with their immense loads and high speeds, have made it necessary to change the design of pavement with the result that our pavements are now not only wider but heavier and more expensive. This development of street design has had a marked effect on the distribution of water.

EFFECT OF WIDER STREETS ON DISTRIBUTION LINES

With the relatively narrow streets of former days, the logical way to distribute water to the separate lots was to lay a single main at or near the center of the street and to install services from this main to each lot on both sides of the street. In many cities these services were installed prior to paving the street, one service being laid for each separate parcel of ground. In other cities, the services were installed as needed with the result that the cost for each individual service was increased, because of the expense of opening and repairing a pavement. As street widths increase, a point is reached where

¹ Presented before the Buffalo Convention, June 9, 1926.

² Research Engineer, Cast Iron Pipe Publicity Bureau, Chicago, Ill.

it becomes more economical to use a two-main system for water distribution, one main being laid on each side of the street in place of a single main near the center. In the two-main system, the pipe on one side of the street is of sufficient size to provide for domestic consumption and to take care of the fire protection for both sides of the street, tapped, however, for services for one side only. The main on the other side is of smaller diameter, usually 4- or 6-inch, depending on the length of line between connections and, unless the street is unusually wide, should have no fire hydrants connected to it. In mentioning these sizes, it is presumed that the width of the street is not so great as to necessitate providing hydrants on both sides. If it should become necessary to have fire hydrants on both sides, the smaller of the two mains should be large enough to provide water for fire protection as well as for domestic supply. These two mains should be cross connected about every two blocks and properly valved. Each of these mains should be laid about 4 feet from the lot line or, if the sidewalks are laid immediately adjacent to the lot line, it might be advisable to lay these pipes about 1 foot from the outer edge of the walk.

With this type of distribution system, service pipes can be installed when buildings are being constructed. This makes it possible to install a service pipe of the proper size and at the proper location for each building and does away with the installation of service pipes for each separate parcel of ground prior to paving.

With the old scheme in vogue, many services were installed that were never used and many that were properly located were not large enough to take care of the size of building that was later constructed. The result is that many dead services now exist in our streets which represent an investment of a considerable amount of money and which have never been put to any use. The loss is not limited to money spent in laying these services, since we know it to be a fact that dead services are a prolific cause of trouble and it very often becomes necessary finally to cut them off at the main in order to keep down maintenance costs.

The use of the two-main system also eliminates the necessity of any service pipe crossing the street and puts the mains in parkways where the cost of digging up leaks is likely to be less than when pavements must be opened and later repaired. While the use of this system results in a greater mileage of main to be maintained, it cuts down the number and mileage of services to an even greater extent.

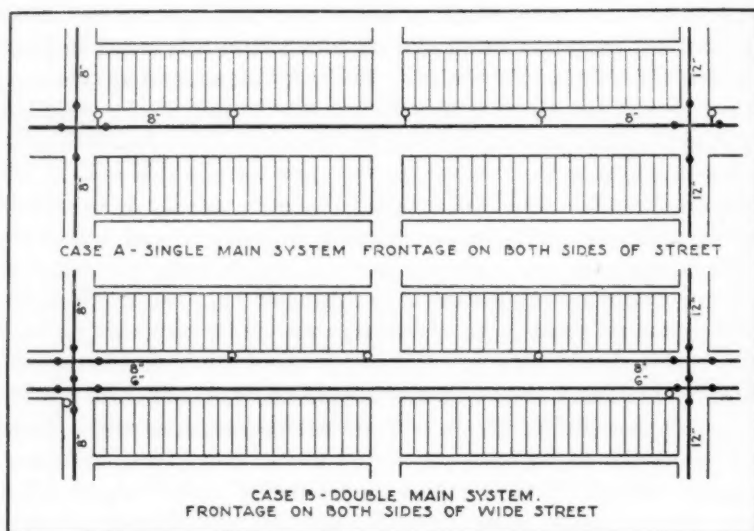


FIG. 1. PLANS FOR SINGLE AND DOUBLE MAIN WATER SYSTEMS

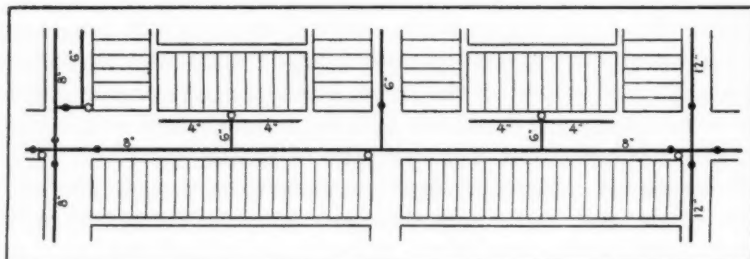


FIG. 2. PROPERTY FRONTING ON ONE ENTIRE SIDE AND PARTS OF OTHER SIDE

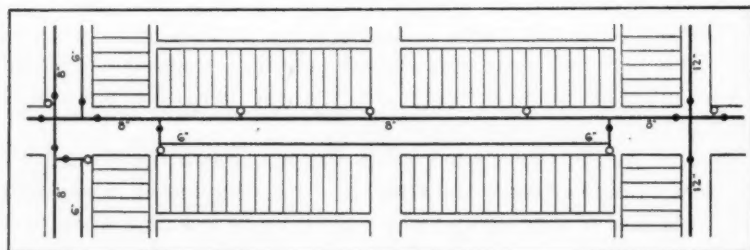


FIG. 3. PROPERTIES FRONTING PARTLY ON ONE BLOCK AND PARTLY ON ANOTHER

It also reduces the cost of maintenance by putting the mains inside of the curbs where any leaks that occur can be easily located without expensive openings and without traffic interference. The removal of water mains and services from the proximity of street car tracks,

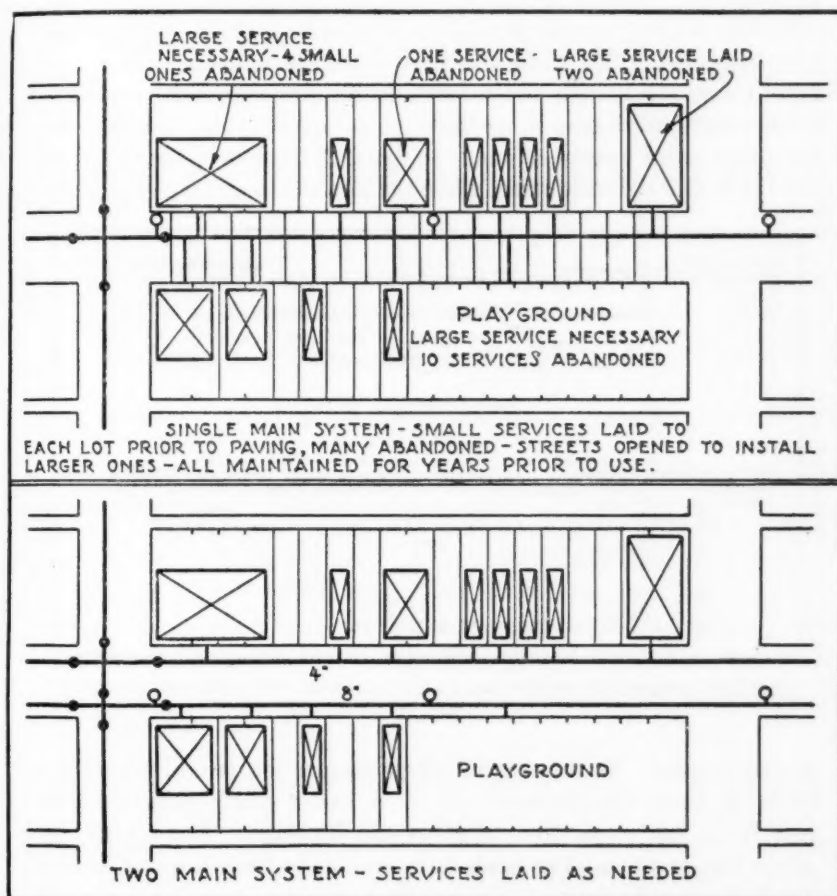


FIG. 4. SAVING OF SERVICES IN DOUBLE AS COMPARED WITH SINGLE MAINS

telephone cables and other possible carriers of return current, will cut down the amount of damage due to electrolysis.

There are cases where it is physically impossible to lay mains inside of the curb line, as, for instance, when the subsidewalk space is vaulted over and used by the property owner. In other cases rows

of trees might interfere with the use of digging machines for installing the pipe when these machines might be used to advantage if the main were laid in the street. Even in these cases, the actual cost of the two main system should be estimated by the engineer in order to determine whether or not it would be economical.

In figures 1 to 5 several plans are indicated for providing services for property sub-divided along different lines. In figure 1, case A, we have a wide street with all the lots facing it and supplied by a single main. In figure 1, case B, we have the same lot layout, but supplied from two mains instead of one. In figure 2, the lots in the center of the block face the wide street while the lots at the end face the inter-

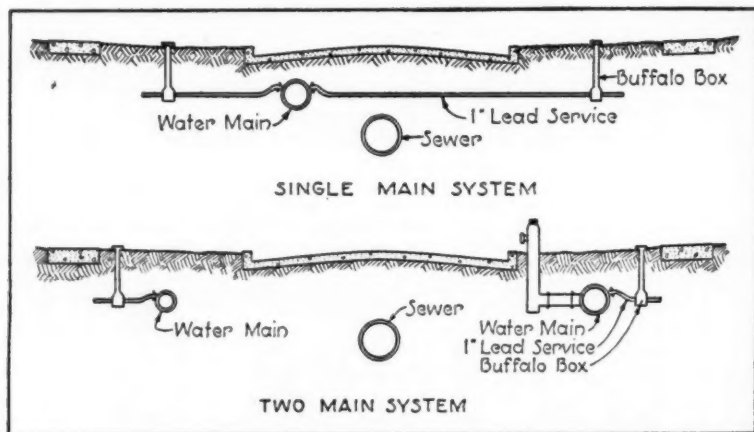


FIG. 5. COMPARISON OF METHODS FOR ARRANGING SINGLE AND DOUBLE MAINS

secting streets. In this case a single connection is laid across the street at about the center of the block and a small main laid each way from this connection to cover the frontage. The connection across the street could be made large enough to furnish water for one fire hydrant. In figure 3, the lots at one end of each block do not face the street in question. The second main is then laid to cover only the lots that actually face on the wide street. Additional details are shown in figures 4 and 5.

COSTS OF SINGLE COMPARED WITH DOUBLE MAINS IN WIDE STREETS

As an example of the relative cost of the two types of installation, we shall assume a street laid out so that each block consists of seven-

teen 30 foot lots and two 42 foot lots on each side of the street. A roadway of 42 feet is to be provided. The cost of the single main system for this street would be:

1320 feet, 8-inch main installed @ \$2.32.....	\$3062.40
2 feet, 8-inch valves installed including basin.....	170.00
76 feet, 1-inch lead services (2280 feet) including all labor and material @ \$1.29 a foot.....	2941.20
Total.....	\$6173.60

The cost of installing a two-main system to supply the same frontage would be:

1320 feet, 8-inch main installed @ \$2.32.....	\$3062.40
1320 feet, 4-inch main installed @ 1.35.....	1782.00
2 feet, 8-inch valves and valve boxes.....	100.00
2 feet, 4-inch valves and valve boxes.....	60.00
76 feet, 1-inch lead service (228 ft.) @ 1.29.....	294.12
Total.....	\$5298.52

In the above estimate, it is assumed that the services in the single main system would extend to a point nine feet back of the curb and that in the two-main system each service would be 3 feet long. Under these conditions, the saving in original cost of the two-main system would be \$875.08, assuming that all services were laid. In the case of the two-main system, certain services would be omitted, due to the fact that some buildings would occupy two or more lots and the real saving would consequently be even larger than indicated by the above figure.

As the width of the street increases, the relative saving increases and the costs are also affected by the cost of installing service pipes and by the width of the lots. The case is cited as an example and is not meant to cover all instances. The relative cost of the single and two-main system will be affected by local conditions. While the estimate given above may not apply to all cases, it at least points out the possibilities of economy in using the two-main system.

THE WATER SUPPLY PROBLEMS OF TENNESSEE¹

BY HOWARD R. FULLERTON²

From topographical, mineral, agricultural and geographical standpoints, the State of Tennessee is naturally divided into three divisions. It follows that the water supply problems vary considerably over these three divisions and over the entire State. In eastern Tennessee with its mountains, rapidly running streams, and coal resources there has been an unprecedented industrial development. This has brought together large numbers of people unaccustomed to community life. This condition has increased very much the problem of obtaining safe water supplies for all residents in these fast growing and sometimes new communities. Central Tennessee has also undergone considerable growth and industrial expansion. The topography of the land is that of a plateau region, of limestone formation in the eastern part, grading to a lowland adjoining the Tennessee River on the West. The western grand division of the state lies between the Tennessee and Mississippi Rivers, and the majority of the territory is low, with sluggish and often overflowing streams. There is little of any outcropping of rock in this territory. The majority of the strata are intermittent layers of sand and clay for a depth of several hundred feet. Traces of iron and sulphur occur in some of the strata.

EAST TENNESSEE WATER PROBLEMS

In east Tennessee practically all of the water supplies are from springs or streams. In many instances the springs show some contamination, but are of sufficient clarity throughout the year that a potable water can be produced with chlorination only. Other spring supplies are sometimes turbid, and some are so abundantly supplied with sulphates and carbonates that softening is necessary as well

¹ Presented before the Kentucky-Tennessee Section meeting, January 20, 1927.

² Director, Division of Sanitary Engineering, State Department of Public Health, Nashville, Tenn.

as filtration. Two water supplies in eastern Tennessee of this latter type and class are at Greenville and Bristol.

After a town grows to the proportion of a city and the demands for water have increased accordingly, usually the water supply has to be considered from a volume standpoint first. The volume can, with few exceptions, be supplied only from a river. Several East Tennessee cities have now reached these proportions. Knoxville has secured its water for years from the Tennessee River. Johnson City has just had a survey completed for a new river supply and Kingsport will soon have to augment its present spring supply, most probably from the north branch of the Holston River.

MIDDLE TENNESSEE

This section in the eastern and central part is almost entirely underlaid with limestone formation with the bed rocks protruding at the surface or at best with only a few feet of earth on top.

In the western part near the Tennessee River, clay and sand strata are in evidence.

The peculiarity of underground waters in limestone, in that they will often flow for miles without receiving any natural filtration, tremendously increases the problem not only of securing an adequate water supply without excessive cost, but creates the additional problems of maintaining the supply safe for drinking and general domestic use after it is obtained. All of the well supplies in the middle section of the state are chlorinated where necessary and all of the spring supplies are so treated to make them safe. Nashville, Columbia and Shelbyville secure their supplies from rivers. They use coagulation, sedimentation, filtration and chlorination, with the exception of Nashville which does not filter. Bonds, however, have been voted and \$1,500,000 are available to build the filters. Pumping equipment, both low and high lifts, has been bought and installed.

In the western part of middle Tennessee one of the water supplies is secured from a well, the others from springs.

WESTERN TENNESSEE

All of the municipal water supplies between the Tennessee River and Mississippi River are secured from wells. The city of Memphis has the largest municipal supply in the county secured exclusively

TABLE 1

Distribution of public water supplies in Tennessee, by population groups

GROUP	POPULATION OF TOWNS IN GROUPS HAVING PUBLIC WATER SUPPLIES	PER CENT OF TOTAL POPULA- TION IN GROUPS LIVING IN TOWNS HAVING PUBLIC WATER SUPPLY	NUMBER OF TOWNS HAVING PUBLIC WATER SUPPLIES	NUMBER OF TOWNS IN GROUP WITH NO WATER SUPPLY
20,000 and up	493,807	100	5	0
20,000-10,000	17,806	100	1	0
10,000-6,000	54,619	100	7	0
6,000-4,000	67,235	100	14	0
4,000-3,000	42,915	100	13	0
3,000-2,000	46,719	100	18	0
2,000-1,500	20,623	92.6	12	1
1,500-1,000	26,427	82.4	22	4
1,000-750	8,430	50.6	10	10
750-500	11,260	46.1	19	22
500-400	4,807	43.2	11	13

TABLE 2

Status of Tennessee water supplies

TYPE OF TREATMENT	NUMBER OF SUPPLIES
No treatment.....	77
Disinfection only.....	26
Coagulated, settled.....	1
Coagulated, settled, disinfected.....	2
Coagulated, settled, filtered.....	2
Coagulated, filtered, disinfected.....	1
Filtered, disinfected.....	2
Coagulated, filtered, settled, disinfected.....	24
Liquid chlorine.....	45
Hypochlorite of lime.....	8
Other disinfection (ultra violet ray).....	1
Laboratory control:	
Chemical and bacteriological.....	10
Chemical only.....	1
Source:	
Wells.....	60
Springs.....	51
Surface.....	22

from wells. Much of the water in the western third of our state is impregnated to a more or less degree with sulphur and iron. The cities of Paris, Dyersburg, Ripley and Memphis are equipped for

partial or entire removal of these unsatisfactory materials in the water. Covington is also experimenting with the water from one of its deep wells for carbon dioxide removal and is using aeration. Several other cities need treatment for removal of these undesirable materials from these waters.

THE PROBLEM OF DEVELOPING MUNICIPAL WATER SUPPLIES WHERE THEY ARE NEEDED

Table 1 shows the distribution of public water supplies for the cities by population groups.

The total population of state is 2,430,144, of which 32.6 per cent live in towns having public water supplies.

The status of water supplies already developed is shown in table 2. Of the 133 public water supplies, 79 are municipally, and 54 privately owned.

PROBLEMS OF OPERATION AND MAINTENANCE

As previously stated, there are 133 public water supplies in the state and they are distributed in cities ranging from 500 to 181,100 in population. These water supplies are of every sort and description and of almost every conceivable combination of processes.

The smaller cities and towns cannot in most instances pay for the desired class of water works operators because their revenues are too small. Some of the plants were constructed when water works practice was not developed to as high a degree as it is now. On new construction, sometimes a consulting engineer will contract to build a water plant when not so well qualified for the work as he might be.

The Tennessee State Department of Health early recognized that water supplies constitute one of the major sanitary engineering problems of any state. No other one single problem affects the health of so many people in a built-up community. The Department further realized that few, if any other problems, when properly solved will make for a higher standard of public health.

The larger plants in the state have competent supervision. In order to maintain the water supplies in a satisfactory condition each plant is visited twice a year by a sanitary engineer. He looks over the plant for needed repairs and extensions and instructs the superintendent in its scientific operation from mechanical, chemical and bacteriological standpoints. Outside of the four large cities only

a few plants are doing bacteriological work, but this type of control is being recommended where it is believed to be possible.

Water works plants that use liquid chlorine have been furnished by the Division of Sanitary Engineering an inexpensive chemical testing outfit for testing for free chlorine. In this manner sufficient chlorine can be kept in the water to kill the bacteria, but not enough to be objectionable to taste. Although a bacteriological analysis may be made only once each month, the same amount of chlorine can be kept in the water as when the latter was examined and a safe water be reasonably assured for the rest of the month.

The water works are required, except in the four large cities, to submit water samples once each month to a state laboratory for analysis. The analyses are received by the Division of Sanitary Engineering and where results are poor the water works owners are communicated with at once and instruction given as to how to remedy the undesirable situation. A visit to the plant is also made when needed. Regulations require the submission of monthly operating charts and these are also reviewed and instruction given where improvements are needed.

It is necessary that the traveling public be protected against contaminated water on trains. The State Health Department coöperates with the United States Public Health Service in this matter and makes a survey of each water supply and bacteriological examinations of the water.

No discussion of water supply problem in Tennessee would be complete without some mention of stream pollution. With the rapid industrial development now taking place, stream pollution and its effect upon water supplies secured from these streams is receiving more and more attention by the State Department of Health through the Division of Sanitary Engineering. A sanitary engineer has been assigned to this work to make a complete study of it during the year 1927.

The problem is not only inter-state but also intra-state. We must not only protect the surface water supplies of our state against trade wastes and too heavy sewage contamination arising within our own boundaries, but protection must be provided against sources originating outside of the state.

We have already done a considerable amount of work on preventing stream pollution by domestic sewage, as all new municipal sewerage plans have been approved only after satisfactory plans for sewage disposal have been included in the design.

WATER SOFTENING AS AN ADJUNCT TO WATER PURIFICATION¹

BY CHARLES P. HOOVER²

During the past five years municipalities having a raw water supply with a hardness in excess of 150 p.p.m. have been looking with favor toward water softening and as far as I know all municipalities, during this period, that have had occasion to build plants to improve their water supply, have in all cases, where the hardness exceeded 150 p.p.m., included softening.

Water works engineers have long recognized the economic results obtained by softening and many articles have been written calling attention to the losses occasioned by the use of hard water. The wastage of soap and other preparations for softening water has been emphasized as well as the extra expense of cisterns and double plumbing systems. The evil effects on fabrics, heat losses in hot water heaters and boilers and extra expense for operating steam boiler plants have also been calculated.

The consumers, of course, do not have a very definite idea as to the extent of the losses due to the use of hard water, but they fully appreciate the inconveniences with which they must contend on account of hard water. These inconveniences from hard water are perhaps noticed more by women than by men, because in the home, at least, they have occasion to use more of it.

The annoyances from hard water manifest themselves principally in the formation of scum in bath tubs, in laundry work, dish washing and the stopping up of water meters, heaters and pipes.

The added comforts of a softened water supply which the citizens of any community will experience by the change from hard to soft water cannot be fully appreciated until after it has been made.

The disadvantages of hard water and the economic losses from its use have long been recognized, nevertheless, until within the

¹ Presented before the Illinois Section meeting, January 27, 1927.

² Chemist in charge, Water Softening and Purification Works, Columbus, Ohio.

last five years, very few municipal water softening plants have been built and we may well ask why.

WHY SO FEW SOFTENING PLANTS WERE BUILT

There are several reasons why municipal water softening has not been looked upon with complete favor in the past. They are, as follows:

1. In the early days of the art of water softening, lime softened water was not stable because it was super-saturated with normal carbonates of calcium and magnesium and distribution systems carrying the water would become clogged with deposits of these carbonates and difficulty with the deposits were also encountered in meters and hot water systems. An extra amount of trouble was encountered with hot water pipes in hotels and public buildings stopping up on account of deposits formed in pipes, due to the fact that the water in these buildings is usually heated to a very high temperature.

2. Construction of water softening plants have always been regarded as very expensive because it was considered necessary to build large basins in which to store the water previous to filtration in order to allow long periods of time for chemical reactions to be completed.

3. Methods for handling, storing and applying large quantities of chemicals were crude.

4. The disposal of the large quantities of sludge formed by the softening reactions was a troublesome problem, and

5. The limited results that could be obtained in reduction of hardness on account of the increased solubility of substances causing alkalinity in water following the addition of soda ash.

Almost all of the difficulties and objectionable results obtained following water softening have now been entirely overcome and the others have been greatly improved.

RECARBONIZATION AND OTHER DEVELOPMENTS

Lime softened water may be cheaply and satisfactorily stabilized by recarbonizing it with carbon dioxide produced by burning coke, pulverized coal, oil or gas in a suitable furnace and forcing the gas, after being passed through a scrubber and drier, into the water. This gas is diffused into the water through small openings

in a grid system and is applied to the water after it has passed through the settling basins and before it reaches the filters. The carbon dioxide converts the normal carbonates, which are only slightly soluble, to bi-carbonates, which are highly soluble, and will, therefore, not be easily precipitated from the water.

Chemicals used for softening can be thoroughly and satisfactorily mixed and agitated with the water in improved mechanical mixing devices which can be built at less cost than the old type baffled tanks, and the chemical reactions should be completed as far as possible in the mixing basin. If they are well completed in the mixing basin, the settling basin need not be much larger than that provided with ordinary filtration plants.

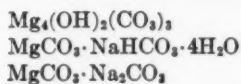
Large quantities of chemicals can be economically handled by unloading from the cars by means of power shovels or air suction devices and they may be cheaply elevated into bins from which they are subsequently fed into the water by gravity.

Dry feed machines for measuring the chemicals and othersequipped with continuous lime slakers have been developed. Their introduction permits the elimination of chemical solution tanks with all the attendant difficulties, familiar to water works operators.

Apparatus has been developed which may be installed in the settling basins or clarifiers making it possible to remove the sludge produced from the water softening reactions continuously. Practically all of the municipal water softening plants built within the last five years have been provided with Dorr clarifiers for removing sludge continuously.

USE OF COAGULANTS IN SOFTENING

The limited results that could in the past be obtained in reduction of hardness seems to be largely due to the fact that the soda ash combines with the magnesium salts present in the water and forms complex basic carbonates or a complex double salt of sodium, magnesium, basic carbonates or perhaps colloidal precipitates of these salts. They may be represented by the following formulae:



The basic carbonates are formed even when lime alone is used as a softening reagent, if the water being treated contains magnesium

carbonate, but we know that water high in non-carbonate hardness is more difficult to soften than water with an equivalent amount of hardness, but low in non-carbonate hardness, because non-carbonate hardness requires soda ash for its removal and large amounts of soda ash are conducive to the formation of these basic carbonates.

It has, of course, long been recognized that the product of the reaction between lime and bi-carbonates in the water is not an entirely insoluble compound. About two grains per gallon (34 parts per million) of the calcium and magnesium compounds remain in the solution; so that by the lime-soda ash treatment, it is theoretically, not possible to reduce the hardness to less than two grains per gallon. If it were possible to reduce the hardness of the water treated to two grains per gallon by adding the theoretical amounts of lime and soda ash required to combine with the carbonate and non-carbonate hardness salts, the limitation of being able to obtain a two-grain water would not be especially objectionable, for two grain hardness water is satisfactory for almost all purposes. Unfortunately, however, in past practice it has been impossible to reduce the hardness of a hard magnesium water by the lime-soda ash process to two grains per gallon unless the water being softened was heated or unless excess lime and soda ash were added. Over-treated cold, softened water usually contains from two to four grains of sodium hydroxide because, as has already been stated, to reduce the hardness of water to two grains per gallon, more chemical than is theoretically required, must be used. That is, excess lime must be added in order to precipitate completely the bi-carbonate of calcium and magnesium and sufficient soda ash added to neutralize the non-carbonate hardness, plus an additional amount to convert the excess CaOH to NaOH , as shown by the formula, $\text{Ca(OH)}_2 + \text{Na}_2\text{CO}_3 = 2\text{NaOH} + \text{CaCO}_3$. Excess treatment increases the cost to between five and six dollars per million gallons and if practiced at the Columbus plant, where it is the policy to leave approximately 30 to 35 parts per million of non-carbonate hardness in the water, the cost of excess treatment would be increased about \$10.00 per million gallons. The treatment also introduces into the treated water salts that are conducive to foaming when the water is used for boiler feed purposes.

Results of experimental tests conducted at the Columbus plant indicate that by the addition of a coagulant such as sulfate of alumina or sodium aluminate (3 to 5 grains) along with the lime and soda

ash, the hard water from the Scioto river may be satisfactorily softened to a hardness of between 35 and 50 parts per million without resorting to excess treatment with lime and soda ash, whereas, without the use of coagulant the limit seems to be somewhere between 90 and 100 parts per million.

It has already been explained that the addition of soda ash to remove the non-carbonate hardness is largely responsible for the formation of soluble hardness salts. Now we know that it is not necessary and in many cases not advisable to use soda ash to remove permanent or non-carbonate hardness from water in communities where salt may be obtained at a fair cost, because it is cheaper to remove non-carbonate hardness by means of the zeolite process than by soda ash.

ZEOLITE PROCESS

Zeolite softening material may be a synthetic product or a natural one. The synthetic product is in composition a hydrated sodium aluminium silicate and is being manufactured by several reliable companies. Natural or so called green sand zeolite is found in large quantities in the state of New Jersey. Green sand has the appearance of ordinary filter sand except that it has a green color when dry. It can be graded so as to have an effective size of around 0.4 mm. and a uniformity coefficient of 1.60 which is standard grading for filter sand. It has, like the artificial zeolites, the property of being able to exchange its base, sodium, for the calcium and magnesium in the water that is brought into contact with it. Hard water may be softened to zero hardness by simply filtering it through a bed of the zeolite material. The calcium and magnesium salts in the water are not precipitated as in the lime-soda ash method but are replaced or exchanged, as has already been indicated, by the sodium from the zeolite. In other words, calcium and magnesium are the mineral salts which in solution in water cause it to be hard. When they are replaced by sodium, the water is soft.

When the zeolite has exchanged its sodium for calcium and magnesium it becomes inert and must be regenerated and this is done by passing a solution of common salt (sodium chloride) through the material. Thus the sodium from the sodium chloride washes out or replaces the calcium and magnesium taken from the water and reconverts the zeolite back to its original condition.

Salt Costs for Removing Hardness

One cubic foot of green sand will remove 3000 grains of hardness before being exhausted and according to the results obtained at McKees Rock, Pa., 0.315 pound of salt was required for each 1000 grains of hardness removed. Salt at McKees Rock costs \$6.75 per ton delivered. Based on McKees Rock's figures the salt cost of removing 1 part per million hardness per million gallons equals \$0.062. During the year 1925 the average cost of lime at Columbus, Ohio, for removing 1 part of carbonate hardness per million gallons was \$0.057, and the average cost of soda ash for removing 1 part per million permanent or non-carbonate hardness per million gallons was \$0.125. These figures show that the cost for salt or softening water through zeolite is only about one half the cost of soda ash for removing non-carbonate hardness. In addition to the salt cost, an extra allowance should be made for wash water when using the zeolite method as about 10 per cent wash water is wasted in this process.

Advantages of Zeolite Process

The zeolite process offers several advantages over the soda-ash-treatment in addition to cost. First, the complications of reactions, referred to in an earlier paragraph of this paper and explained in detail in the 1925 report of the Division of Water, Columbus, Ohio, are eliminated and, second, water of any degree of hardness may be obtained and this is not possible to accomplish with the lime-soda-ash process.

At the Columbus plant it is now planned to take the filter sand out of one of our mechanical filters and replace it with zeolite sand. The operation of this one filter will be regarded as an experiment and the results obtained from its operation will probably determine whether or not more of the filters will be converted into zeolite softeners.

OPERATION OF LIME-ZEOLITE SOFTENING PLANT

The process of operating a lime zeolite softening plant would be about as follows: The water pumped into the plant would be first treated with sufficient lime to reduce the temporary or carbonate hardness to the lowest possible figure. Lime and alum would be mixed with the water in the mixing tanks and then passed through the settling basins just the same as it does now to remove the pre-

cipitated carbonates. At the end of the settling basins, the lime softened water would be carbonated with carbon dioxide gas in order to convert the normal carbonates to bi-carbonates, thus preventing the deposition of normal carbonates on the zeolite sand and to prevent the formation of normal sodium carbonate in the softened water. The presence of sodium bicarbonate in the zeolite softened water makes it possible to mix it with water containing non-carbonate hardness and not get a precipitation or after reaction. From the settling basins the water would flow to the filters and, if desirable, to reduce it to zero hardness, all the water would be passed through zeolite filters. If it is desirable to leave some residual hardness in the water, then, of course, it would only be necessary to filter a portion of the water through zeolite filters.

At the Columbus plant it is believed that it will be possible to reduce the hardness of the water to 160 parts per million with the lime treatment alone and that in order to produce a softened water with a total hardness of say 80 parts per million, it will be necessary to filter only half of it through zeolite filters, reducing the hardness of one-half portion to zero, and then mixing it with the other half portion having a hardness of 160 parts per million giving a resultant product with a hardness of 80 parts per million. No after reactions are expected, because the residual sodium salts in the zeolite softened water are present as bi-carbonates.

DIFFERENCES BETWEEN WATER FILTRATION AND WATER SOFTENING

The principal differences between a water filtration plant and a water softening plant are: 1. A water softening plant must have additional facilities for storage of chemicals and their application to the water. 2. More adequate mixing devices for agitation of the chemicals with the water are required. 3. A mechanism for continuously removing the sludge. 4. A carbonization plant.

With the addition of these facilities almost any water purification plant may be converted into a softening plant and the extra cost of including these facilities at the time of building a plant is not great when the advantages to be obtained by softening a hard water supply are considered.

ADDED ADVANTAGES OF SOFTENING

In addition to the added comforts and benefits which the citizens of any community will experience by the change from hard to soft

water, the softening process increases the efficiency of the filtration plant operation because better coagulation is effected, more organic matter and color are removed, iron, if present, is eliminated, the treated water is non-corrosive, and intestinal and pathogenic bacteria are killed.

At the Columbus plant the bulk of the precipitate formed by the softening reactions is about 20 times as great as could be obtained by ordinary coagulation processes. The efficiency of this large volume of precipitate, as a coagulant, is greatly increased, if the water treated contains magnesium compounds, because the lime reacts with them to form magnesium hydroxide, a bulky gelatinous precipitate which coagulates the suspended clay particles or mud as readily as the precipitates formed by sulphates of alumina or iron. If the quantity of magnesium salts is small in the water being softened, then of course a small quantity of coagulant may be added, along with the softening chemicals, in order to make the precipitate formed more gelatinous and thus rendering it more efficient as a coagulant.

A properly lime softened water should have, at the time it is ready to leave the settling basins, a bright greenish look and a turbidity not to exceed 1 or 2 parts per million. One should be able to see an object immersed in it to a depth of at least 5 feet. Such a water in addition to being low in turbidity will be low in color and organic matter and practically free from intestinal and pathogenic bacteria. The load on the filters will be greatly lessened and filter costs reduced because filtration rates may be increased. The load applied to the filters should be so light that filter runs should be lengthened to at least 48 hours between washings. At the Columbus plant filters have on special occasions been run continuously for periods of six days between washings.

Coagulation, filtration and chlorination can be used in almost all instances to produce a water that is clear and safe for drinking purposes, but sometimes the amount of chlorine required to make sure that the water is safe bacterially is so high that the treated water may not be palatable on account of disagreeable tastes and odors.

It is well known that, if water contains a slight amount of phenol or large amounts of organic matter, the addition of chlorine will intensify any tastes or odors that may be present in the water.

EXCESS LIME FOR DISINFECTION

Dr. A. C. Houston, Chemist of the Metropolitan Water Board, London, England, first proposed the excess lime method of sterilizing water. His results were confirmed by Hoover and Scott at Columbus, Ohio,³ and have since been confirmed at a number of other water softening plants.

Scott and McClure, experimenting with Ohio water supplies at Youngstown, Defiance, Bellaire, Cincinnati, Niles and Sandusky, found that in those plants using enough lime to produce a water with a pH value greater than 9.5, *B. coli* were not found in 50 cc. portions out of a total of 25 samples tested. At those plants where only enough lime was added to assist in coagulation and the pH value was less than 9.5, *B. coli* were present, with one exception, in 22 samples, in 50 cc. portions and usually in 10 cc. portions. They conclude that bacteria of the colon typhoid group are destroyed in media of low hydrogen-ion concentration, the limiting value being 9.5. A natural water treated with the theoretical amount of lime required to soften it will have a pH value of approximately 9.5.

At the Columbus plant it is customary to omit the chlorine treatment entirely during flood periods when the organic matter is high and the water has a tendency to have an unpleasant taste or odor. At the time when chlorine treatment is cut out, excess lime treatment is resorted to, about 20 p.p.m. caustic alkalinity being carried in the filtered water. This amount of caustic alkalinity is not noticeable to the consumer.

³ National Lime Association Bulletin. Water Softening.

TYPHOID FEVER IN THE LARGE CITIES OF THE UNITED STATES IN 1926¹

The Journal presents its fifteenth annual survey of typhoid fever mortality in the seventy-eight cities of the United States that had more than 100,000 population in 1926.² As in the fourteenth report, the cities have been grouped according to the recognized divisions of the U. S. Census Bureau. One city (Jacksonville) appears for the first time in our tables.³

The cities of the New England group (table 1) make a remarkable showing, and one that would be creditable to any similar population group anywhere in the world. No less than seven of the twelve New England cities report typhoid death rates of less than 1 per hundred thousand of population. The total rate for the group (1.51) is the lowest for any geographic division in the United States (table 11). Two New England cities (New Bedford and Lowell) have had rates under 1 per hundred thousand of population for two years in succession, the average for the two years in Lowell being under 0.5 per hundred thousand, or less than one-twentieth of the average for the quinquennium 1911-1915. Cambridge almost alone among New England cities seems to have had an undue number of deaths from typhoid in 1926, its rate (4.9) being more than three times the New England average. It will be remembered that this city also had a high typhoid year in 1921, with a rate of 10.8. The occasionally ex-

¹ Reprinted from the Journal of the American Medical Association, 88: 15 April 9, 1927, p. 1148.

² The preceding articles were published in Jour. Amer. Med. Assoc., May 31, 1913, p. 1702; May 9, 1914, p. 1473; April 15, 1915, p. 1322; April 22, 1916, p. 1305; March 17, 1917, p. 845; March 16, 1918, p. 777; April 5, 1919, p. 997; March 6, 1920, p. 672; March 26, 1921, p. 860; March 25, 1922, p. 890; March 10, 1923, p. 691; Feb. 2, 1924, p. 389; March 14, 1925, p. 813, and March 27, 1926, p. 948.

³ The deaths from typhoid in each city are those reported to us by the respective health departments. The rates have been calculated on the basis of the midyear 1926 population as estimated by the U. S. Bureau of the Census. In the nine instances in which such estimates were not available, the midyear population figures were furnished by the health departments of the respective cities.

cessive typhoid in Cambridge in recent years is all the more noteworthy since, for the sixteen years 1906-1920, this city had easily the best typhoid record in New England.

In the Middle Atlantic states (table 2) three cities (Albany, Utica, Yonkers) achieve the proud distinction of having had not a single typhoid death in 1926. The other cities of the group for the most part make an admirable showing. Attention may be called especially to the remarkable records of Philadelphia and Pittsburgh in 1926, as

TABLE 1
Death rates of cities in New England States from typhoid per hundred thousand population

	1926	1925	1921-1925	1916-1920	1911-1915	1906-1910
Worcester.....	0.5	2.1	2.3	3.5	5.0	11.8
Bridgeport.....	0.6*	2.8†	2.2	4.8	5.0	10.3
New Bedford.....	0.7‡	0.8	1.7	6.0	15.0	16.1
Providence.....	0.7	3.4	1.8	3.8	8.7	21.5
Springfield, Mass.....	0.7	1.4	2.0	4.4	17.6	
Fall River.....	0.8	1.5	2.3	8.5	13.4	13.5
Lowell.....	0.9§	0.0	2.4	5.2	10.2	13.9
Hartford.....	1.2	1.9	2.5	6.0	15.0	19.0
Boston.....	1.8	3.5	2.2	2.5	9.0	16.0
New Haven.....	2.2	1.7	4.4	6.8	18.2	30.8
Lynn.....	3.8	1.0	1.6	3.9	7.2	14.1
Cambridge.....	4.9	1.7	4.3	2.5	4.0	9.8

* Rate calculated on population figures furnished by the health department: 170,717.

† Rate calculated on figures for population in 1922.

‡ Rate calculated on population figures furnished by the health department: 135,132.

§ Rate calculated on population figures furnished by the health department: 112,759.

contrasted with the typhoid rates from which these cities suffered in the period 1906-1910. Those who are inclined to minimize or to forget the importance of water-borne typhoid may well ponder these figures. Philadelphia, a city with distinctly less favorable climatic conditions than New York and presumably with a high legacy of typhoid carriers from the long period when typhoid ravaged the city, now rivals New York in its low typhoid rate. In Pittsburg the average typhoid mortality in the years 1906-1910 was nearly twenty-

five times as great as the typhoid rate for 1926. The typhoid records in these two great cities constitute an outstanding demonstration of the efficacy of water purification.

Two of the Middle Atlantic cities (Rochester and Scranton) are somewhat out of line with the rest of the group in that they not only had in 1926 a considerable higher typhoid mortality than in 1925, but also a higher rate than for the two preceding five year periods. Camden shows a decline in 1926 as compared with 1925, which is an en-

TABLE 2
Death rates of cities in Middle Atlantic States from typhoid per hundred thousand population

	1926	1925	1921- 1925	1916- 1920	1911- 1915	1906- 1910
Albany.....	0.0	5.9	5.6	8.0	18.6	17.4
Utica.....	0.0	3.9				
Yonkers.....	0.0	1.8	1.7	4.8	5.0	10.3
Syracuse.....	1.1	2.2	2.3	7.7	12.3	15.6
Paterson.....	1.4	2.1	3.3	4.1	9.1	19.3
Newark, N. J.....	1.5	0.9	2.3	3.3	6.8	14.6
Jersey City.....	1.9	4.1	2.7	4.5	7.2	12.6
New York.....	1.9	3.3*	2.6	3.2	8.0	13.5
Philadelphia.....	1.9	2.3	2.2	4.9	11.2	41.7
Trenton.....	2.2	3.8	8.2	8.6	22.3	
Reading, Pa.....	2.6	0.9	6.0	10.0	31.9	42.0
Pittsburgh.....	2.7	3.2	3.9	7.7	15.9	65.0
Rochester.....	4.0	1.9	2.1	2.9	9.6	12.8
Scranton.....	4.2	0.0	2.4	3.8	9.3	31.5
Camden.....	4.6	7.0	5.9	4.9	4.5	
Buffalo.....	5.0	4.5	3.9	8.1	15.4	22.8

* Rate calculated on figures for population in 1924, with same annual increment added as in 1922-1923, 1923-1924.

couraging indication. An explanation seems to be warranted about the Buffalo rate which, as reckoned according to the ordinary methods, gives a somewhat false impression. It is officially reported that ten of the twenty-seven deaths in that city in 1926 were from cases contracted in a neighboring community which suffered from a severe outbreak. Making allowance for this unusual occurrence, the record of typhoid infection in the city of Buffalo itself would seem to have been excellent. The rate for the whole geographic division (table 11) in 1926 (2.12) was much lower than in 1925 (3.01).

The cities of the South Atlantic states (table 3) show a slight improvement, the rate for the geographic group dropping from 5.71 in 1925 to 5.38 in 1926 (table 11). The rate in the national capital (Washington, D. C.) is relatively very low (2.5) and marks a gratifying decrease over the previous low record (3.7 in 1919). Richmond also makes a fine showing. Atlanta, almost alone in this group, has shown little change for the better in the last ten years.

The cities in the East North Central states (table 4) again make an excellent record. One city (Youngstown) does not have a single typhoid death to its discredit. Chicago establishes a new low record,

TABLE 3
Death rates of cities in South Atlantic States from typhoid per hundred thousand population

	1926	1925	1921- 1925	1916- 1920	1911- 1915	1906- 1910
Norfolk.....	1.7	1.5*				
Wilmington.....	2.4	3.3	4.7			
Washington.....	2.5	5.0	5.4	9.5	17.2	36.7
Richmond.....	2.6	5.4	5.7	9.7	15.7	34.0
Baltimore.....	4.7	3.6	4.0	11.8	23.7	35.1
Jacksonville.....	8.8					
Atlanta.....	17.2†	18.4‡	14.5	14.2	31.4	58.4

* Rate calculated on figures for population in 1924, with same annual increment added as in 1922-1923 and 1923-1924.

† Rate calculated on population figures furnished by the health department: 266,488.

‡ Rate calculated on population figures furnished by the health department: 250,000.

the rate (0.8) being the lowest reported in 1926 for any American city with over 500,000 population. Chicago is one of the cities in which typhoid is carefully watched, a full analysis of the cases being published annually. It is stated in the annual report that the ratio of out-of-town infections to the total cases is about 1:3, and that in more than half of all cases reported the apparent modes of infection have been traced. The Chicago analysis states that in 1926 about 75 per cent of the typhoid cases were treated at hospitals. It is evident that with the increasing rarity of this disease, hospitalization is becoming more practicable, a circumstance that is highly favorable since it affords proper opportunities for control. Two cities in this

group (Toledo and Indianapolis) continue to have rates considerably higher than the average. Columbus and Grand Rapids, which also had high rates in the period 1906-1920, have made considerably better records than Toledo and Indianapolis in recent years.

The four cities in the East South Central states (table 5) appear to be in the worst typhoid belt in the United States. For the second successive year the total rate for this group (table 11) has been higher than that of any other geographic division. Birmingham and Memphis report lower rates in 1926 than in 1925, the figure for Birmingham

TABLE 4

Death rates of cities in East North Central States from typhoid per hundred thousand population

	1926	1925	1921- 1925	1916- 1920	1911- 1915	1906- 1910
Youngstown.....	0.0	2.5	7.2			
Flint.....	0.7	1.5				
Chicago.....	0.8	1.5	1.4	2.4	8.2	15.8
Grand Rapids.....	1.3	1.3	1.9	9.1	25.5	29.7
Cleveland.....	1.4	1.5	2.0	4.0	10.0	15.7
Akron.....	1.5*	1.9†	2.4			
Columbus.....	1.7	4.3	3.5	7.1	15.8	40.0
Milwaukee.....	1.7	1.4	1.6	6.5	13.6	27.0
Detroit.....	2.2	2.7	4.1	8.1	15.4	22.8
Dayton.....	2.3	1.7	3.3	9.3	14.8	22.5
Cincinnati.....	2.7	4.2	3.2	3.4	7.8	30.1
Canton.....	3.6	0.9				
Toledo.....	4.7	6.3	5.8	10.6	31.4	37.5
Indianapolis.....	5.4	3.6	4.6	10.3	20.5	30.4

* Rate calculated on population figures furnished by the health department: 200,000.

† Rate calculated on figures for population in 1924.

being 8.5, which is especially encouraging. Nashville, on the other hand, appears to have suffered early in the summer from an old-fashioned typhoid epidemic, which carried its rate for the year to the highest point reached in any American city (35.0). The highest rate in 1925 was 28.6 (Memphis); and in 1924 the highest was 41.2 (Memphis).

The cities of the West North Central states (table 6) pursue the even tenor of their way, only one city (Kansas City, Mo.) having a higher rate in 1926 than in 1925. Rates in this group show for the

TABLE 5

Death rates of cities in East South Central States from typhoid per hundred thousand population

	1926	1925	1921- 1925	1916- 1920	1911- 1915	1906- 1910
Louisville.....	6.7*	5.8	4.9	9.7	19.7	52.7
Birmingham.....	8.5	9.2	10.8	31.5		
Memphis.....	19.2	28.6	20.3	27.7	42.5	35.3
Nashville.....	35.0	19.8	17.8	20.7	40.2	61.2

* Data for year September 1, 1925 to August 31, 1926.

TABLE 6

Death rates of cities in West North Central States from typhoid per hundred thousand population

	1926	1925	1921- 1925	1916- 1920	1911- 1915	1906- 1910
Duluth.....	0.8	0.9				
St. Paul.....	1.2	2.8	3.4	3.1	9.2	12.8
Minneapolis.....	1.4	3.3	1.9	5.0	10.6	32.1
Omaha.....	1.8	1.9	3.3	5.7	14.9	40.7
St. Louis.....	2.3	3.9	3.9	6.5	12.1	14.7
Des Moines.....	2.7	4.7*	2.2			
Kansas City, Mo.....	3.5	1.9	5.7	10.6	16.2	35.6
Kansas City, Kan.....	4.3	7.7	5.0	9.4		

* Rate calculated on figures for population in 1924, with the same annual increment added as in 1922-1923 and 1923-1924.

TABLE 7

Death rates of cities in West South Central States from typhoid per hundred thousand population

	1926	1925	1921- 1925	1916- 1920	1911- 1915	1906- 1910
Houston.....	6.0*	5.5	7.6			
San Antonio.....	7.8	8.6	9.3	23.3	29.5	
Dallas.....	8.9	17.5	11.2	17.2		
El Paso.....	9.2	3.8	10.8	30.7	42.8	
Fort Worth.....	10.7	5.2	6.1			
Tulsa.....	14.3	20.9				
New Orleans.....	18.6	19.8	11.6	17.5	20.9	35.6

* Rate calculated on population figures furnished by the health department: 250,000.

most part little fluctuation and for the past ten years have been rarely marked by any epidemic prevalence. Duluth, which started out in 1925 with 0.9, repeats this excellent record in 1926.

The cities of the Southwest (table 7), on the other hand, show considerable annual variation. Dallas and Tulsa, which were high in 1925, record substantial reductions in 1926, while El Paso and Fort Worth report considerable increases. The New Orleans typhoid rate appears to be ranging somewhat higher than in the years 1916-1924.

TABLE 8

Death rates of cities in Mountain and Pacific States from typhoid per hundred thousand population

	1926	1925	1921- 1925	1916- 1920	1911- 1915	1906- 1910
Salt Lake City.....	0.7	6.9	6.0	9.3	13.2	
Oakland.....	0.8	1.2	2.0	3.8	8.7	21.5
San Diego.....	0.9	0.9				
Los Angeles.....	1.1*	1.3*	3.0	3.6	10.7	19.0
Seattle.....	2.3†	2.5†	2.6	2.9	5.7	25.2
Portland, Ore.....	2.5§	2.1	3.5	4.5	10.8	23.2
San Francisco.....	2.5	2.2	2.8	4.6	13.6	27.3
Denver.....	3.5	5.0	5.1	5.8	12.0	37.5
Tacoma.....	3.8	1.9	3.7	2.9	10.4	19.0
Spokane.....	6.5	1.8	4.4	4.9	17.1	50.3

* Rate calculated on population figures furnished by the health department: 1,200,000.

† Rate calculated on population figures furnished by the health department: 345,000.

‡ Rate calculated on figures for population in 1924, with same annual increment added as in 1922-1923 and 1923-1924.

§ Rate calculated on population figures furnished by the health department: 314,795.

The cities in the Mountain and Pacific states (table 8) show less proportionate typhoid reduction than those in the other geographic divisions, Portland (Oregon), San Francisco, Tacoma and Spokane all having higher rates in 1926 than in 1925. Spokane, which was on the Honor Roll in 1925 with a rate of 1.8, brings up at the foot of this division in 1926. Oakland, however, which led this list in the quinquennium 1921-1925, again stands very high for the year 1926. San Diego repeats its excellent figure of last year (0.9), and Salt Lake City makes the fine new low record of 0.7.

TABLE 9
Death rates from typhoid in 1926

Honor Roll (from 0.0 to 2.0 Deaths per Hundred Thousand)			
Albany.....	0.0	Syracuse.....	1.1
Utica.....	0.0	Hartford.....	1.2
Yonkers.....	0.0	St. Paul.....	1.2
Youngstown.....	0.0	Grand Rapids.....	1.3
Worcester.....	0.5	Cleveland.....	1.4
Bridgeport.....	0.6	Minneapolis.....	1.4
Flint.....	0.7	Paterson.....	1.4
New Bedford.....	0.7	Akron.....	1.5
Providence.....	0.7	Newark.....	1.5
Salt Lake City.....	0.7	Columbus.....	1.7
Springfield, Mass.....	0.7	Milwaukee.....	1.7
Chicago.....	0.8	Norfolk.....	1.7
Duluth.....	0.8	Boston.....	1.8
Fall River.....	0.8	Omaha.....	1.8
Oakland.....	0.8	Jersey City.....	1.9
Lowell.....	0.9	New York.....	1.9
San Diego.....	0.9	Philadelphia.....	1.9
Los Angeles.....	1.1		
First Rank (from 2.0 to 5.0)			
Detroit.....	2.2	Pittsburgh.....	2.7
New Haven.....	2.2	Denver.....	3.5
Trenton.....	2.2	Kansas City, Mo.....	3.5
Dayton.....	2.3	Canton.....	3.6
St. Louis.....	2.3	Lynn.....	3.8
Seattle.....	2.3	Tacoma.....	3.8
Wilmington.....	2.4	Rochester.....	4.1
Portland, Ore.....	2.5	Scranton.....	4.2
San Francisco.....	2.5	Kansas City, Kan.....	4.3
Washington.....	2.5	Camden.....	4.6
Reading, Pa.....	2.6	Baltimore.....	4.7
Richmond.....	2.6	Toledo.....	4.7
Cincinnati.....	2.7	Cambridge.....	4.9
Des Moines.....	2.7		
Second Rank (from 5.0 to 10.0)			
Buffalo.....	5.0	San Antonio.....	7.8
Indianapolis.....	5.4	Birmingham.....	8.5
Houston.....	6.0	Jacksonville.....	8.8
Spokane.....	6.5	Dallas.....	8.9
Louisville.....	6.7	El Paso.....	9.2
Third Rank (over 10.0)			
Fort Worth.....	10.7	New Orleans.....	18.6
Tulsa.....	14.3	Memphis.....	19.2
Atlanta.....	17.2	Nashville.....	35.0

For the first time since these summaries were undertaken, as many as four cities have got through the year without a death from typhoid, and in more than a dozen others the typhoid rate was less than 1.0. The Honor Roll (cities with from 0.0 to 2.0 typhoid deaths per hundred thousand of population) this year numbers thirty-five, as against thirty last year and eighteen in 1924 (table 9). Six cities have been compelled to take third rank (rates above 10), the same number as in

TABLE 10
*Total typhoid death rate for fifty-nine cities, 1910-1926**

	POPULATION	TYPHOID DEATHS	TYPHOID DEATH RATE PER 100,000
1910	21,125,340	4,143	19.61
1911	21,679,886	3,416	15.71
1912	22,234,865	2,800	12.59
1913	22,788,282	2,923	12.82
1914	23,342,199	2,443	10.46
1915	23,896,616	2,094	8.76
1916	24,368,470	1,874	7.69
1917	24,908,055	1,684	6.76
1918	25,142,605	1,583	6.30
1919	25,702,711	1,006	3.91
1920	26,340,793	934	3.54
1921	26,749,616	992	3.71
1922	27,133,857	862	3.18
1923	27,566,727	866	3.14
1924	28,174,489	870	3.09
1925	28,882,031	993	3.43
1926	29,620,891	822	2.77

* The following nineteen cities are omitted from this summary because data for the full period are not available: Akron, Birmingham, Camden, Canton, Dallas, Des Moines, Duluth, Flint, Fort Worth, Houston, Jacksonville, Kansas City (Kan.), Norfolk, San Diego, Springfield, Tulsa, Utica, Wilmington, Youngstown.

1925. Nashville, Memphis, New Orleans, Atlanta and Tulsa also occupied positions in the third rank last year. Dallas has risen from third to second rank, but Fort Worth has dropped from second into the lowest class, while El Paso, in the first rank in 1925, just escapes being in the third rank in 1926.

The total average typhoid death rate for fifty-nine cities (table 10) is the lowest ever reported (2.77). This is in marked contrast to the rate in 1925, which showed a considerable increase over the three preceding years. Just as emphatically as 1925 was a "bad" typhoid

year, so 1926 was a "good" typhoid year. In 1926 every geographic division except the East South Central states showed a decrease (table 11).

The fact that the large cities in the United States had an actual diminution of 170 deaths from typhoid in 1926, as compared with 1925 (table 10), even although an estimated population increase of nearly a million occurred, should give great satisfaction to the municipal health officers, to whom the credit for this achievement is mainly due.

TABLE 11

*Total typhoid death rate according to geographic divisions—seventy-eight cities in 1926, seventy-seven cities in 1925**

	POPULATION, 1926	1926		1925	
		Typhoid deaths	Typhoid death rate per 100,000	Typhoid deaths	Typhoid death rate per 100,000†
New England states.....	2,521,608	38	1.51	58	2.37
Middle Atlantic states.....	11,399,000	241	2.12	346	3.01
South Atlantic states.....	2,226,488	120	5.38	117‡	5.71‡
East North Central states.....	8,117,000	137	1.69	174	2.19
East South Central states.....	836,000	121	14.47	111	14.30
West North Central states.....	2,479,000	55	2.22	81	3.31
West South Central states.....	1,478,000	173	11.69	180	13.27
Mountain and Pacific states.....	3,430,795	68	1.98	73	2.19

* The table corresponding to this one, in the article Typhoid in the Large Cities of the United States in 1925, was for fifty-nine cities only. The rate it gave for the South Atlantic states (8.12) was an error—the correct rate is 6.35.

† These rates are based on the population estimates for 1925 used in Typhoid in the Large Cities of the United States in 1925.

‡ Does not include data for Jacksonville.

EDITORIAL COMMENT (JOUR. A. M. A.)

The fifteenth annual survey of typhoid mortality, published in this issue, bears testimony to the remarkable improvement in typhoid rates which has occurred in the large cities in this country since these summaries were first undertaken. Data are available throughout the whole period for fifty-nine cities, which in 1910 had a population of 21,125,340 and in 1926 an estimated population of 29,784,917. Despite this population increase of over eight million, the actual number of typhoid deaths fell from 4,143 in 1910 to 822 in 1926, and the rates per hundred thousand of population from 19.61 to 2.76. If the

rate that prevailed in 1910 had been maintained in 1926, the number of typhoid deaths would have been 5,840, or more than 5,000 deaths in excess of the number actually recorded. Since a material reduction in typhoid case fatality rates has not occurred during this period, these figures mean that probably 50,000 cases of typhoid, which would have occurred in our cities in 1926 if the 1910 rate had continued, were prevented. This record is an eloquent tribute to the increasing efficiency of American sanitation.

The decline in typhoid in the large cities is probably representative of a similar decline in the general population. The mortality experience of the Metropolitan Life Insurance Company, covering more than 17,000,000 policyholders, shows that 1926 was marked by the lowest typhoid rate on record in this group (4.2), although this rate is naturally not so low as that for the exclusively urban group (2.76).

It is somewhat surprising that after a period of four years during which marked typhoid reduction did not take place, a distinct increase even occurring in 1925, a rather substantial decline should be reported in 1926, marking indeed a drop of more than 10 per cent below the previous low rate. The fact that this decline was manifest in seven of the eight geographic divisions of the United States may have important epidemiologic implications and is at least worth noting as confirmation of the widespread belief in special "typhoid years."

Great as the improvement has been, let us hope that it is only an earnest of what is to come. Our city typhoid rates still average considerably higher than the rates in a number of European cities. The recent epidemiologic reports of the Health Section of the League of Nations, although not covering exactly the same period, show that in the large cities of England and Wales (with a total population of 19,474,270) the typhoid rate for 1926 was only about 0.7, the rate for London being about 0.6 and that for Birmingham still less (0.45). The German cities as a whole did not do so well, the typhoid rates for forty-six cities (population 16,746,000) being about 2.7. This relatively high rate was due in large part to an unusual prevalence of typhoid in a certain district in Germany in September and October, 1926. The Berlin typhoid rate in 1926 was but little higher (0.8) than that of London, and the Munich rate was lower. There is therefore every prospect that a further shrinkage in typhoid mortality can be brought about in the large cities of the United States, although the progress may not be so rapid a rate in the future as it has been in the past. Urban typhoid mortality in the British Isles has reached a point not quite half what it still is in the best geographic division of the United States.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Rebuilding Reservoir that Failed at South Pasadena. ORMOND A. STONE. Eng. News-Rec., 97: 172-3, July 29, 1926. Illustrated description of reconstruction of Garfield Avenue reservoir in South Pasadena which failed in 1924. Failure believed to have been due to fact that cold joints were laid in pavement slabs with no provision other than thin coating of asphalt over top of crack to allow for contraction of pavement attendant upon cooling of concrete by the water. Also, corners of structure were rounded, apparently without consideration of fact that rounding corners puts tension in pavement on slope. Counterfort walls and Ambursen type walls were considered in planning reconstruction, latter being selected as more economical. Original floor was cut into 15-foot squares and relaid with bituminous mastic joints. Inside face of new concrete work was waterproofed by coating with patent bituminous product. Reservoir was filled before walls were backfilled and close inspection failed to reveal least evidence of seepage.—*R. E. Thompson.*

Investigate Concrete Exposed to Alkali. Eng. News-Rec., 97: 150, July 22, 1926. Results of investigation undertaken by SALISBURY, BRADSHAW, and TAYLOR, Los Angeles, to determine effect of alkali on concrete in alkali soils in Southern California are summarized briefly as follows: (1) Concrete can be made, without use of extraneous substances, which will be immune to injury due to exposure to alkali. (2) Concrete which had deteriorated due to alkali exposure was found to be of inferior quality. (3) It is safe to use high quality concrete in worst alkali if concrete is completely covered with earth totally excluding exposure to air. (4) Leaner mixtures may be specified for dry than for wet alkali soils. (5) As sewer pipes and land drainage tile have part of interior surface exposed to evaporation, concrete should be of first-class quality.—*R. E. Thompson.*

Bottom Recession in Alamo Canal. GLENTON G. SYKES. Eng. News-Rec., 97: 69, July 8, 1926. Data given derived from investigation of scour in Alamo Canal. Scour did not increase in proportion to discharge and maximum scour occurred at much reduced flow. Explanation of phenomenon included.—*R. E. Thompson.*

Making Electrically Welded Pipe for East Bay Conduit. Eng. News-Rec., 97: 128-31, July 22, 1926. Illustrated description of manufacture of pipe for

conduit which will convey Mokelumne River water a distance of 90 miles to East Bay Municipal Utility District in California. Pipe is 65 inches in diameter and is constructed of $\frac{1}{2}$ to $1\frac{1}{8}$ inch steel plates. Welding is carried out by Lincoln automatic carbon arc method. Approximate welding speed with $\frac{1}{2}$ -inch plates is 12 feet per hour. Each length is subjected to severe hydrostatic test. Of 1160 sections tested 35 failed. Pipes are finally dipped in bitumastic compound at temperature of 450–460° and spirally wrapped with soil-proof covering.—*R. E. Thompson.*

Revamping the Corpus Christi Water Works System. Eng. News-Rec., 97: 133–4, July 22, 1926. Brief illustrated description of new pumping equipment installed at Corpus Christi plant which consists of 7 motor-driven centrifugal units with extreme flexibility for double and sometimes triple pumping rates, and an oil-engine-operated generator. Pressure filters formerly employed will be replaced by gravity filters. Average consumption is 1.5 m.g.d. to estimated population of 15,000.—*R. E. Thompson.*

Skillful Blasting of Holes Through Tunnel under 30-Foot Water Head. Eng. News-Rec., 97: 152, July 22, 1926. Brief illustrated description of method of making final blast in tunnel for irrigation system 50 miles from Denver, Colo.—*R. E. Thompson.*

Theoretical Energy Losses in Intersecting Pipes. J. C. STEVENS. Eng. News-Rec., 97: 140–1, July 22, 1926. Mathematical discussion in which general formula is deduced and applied to particular cases such as where water flows from branch into main through a tee and where several pumps discharge into common header.—*R. E. Thompson.*

Irrigation District Served by Series of Pumping Plants. Eng. News-Rec., 97: 224–6, August 5, 1926. Illustrated description of pumping system of Banta-Carbona Irrigation District, supply for which is derived from San Joaquin River. In plant No. 6, equipped with two 20-inch pumps driven by 250-h.p. motors and discharging under 55-foot head, use of automatic control devices for starting and stopping in accordance with water level and power supply has eliminated about 80 per cent of attendance ordinarily required in pumping systems of this size.—*R. E. Thompson.*

New Form of Bank Protection on the Sacramento River. PAUL BAILEY. Eng. News-Rec., 97: 190–1, July 29, 1926. Illustrated description of new form of bank protection consisting of current controls, composed of tree trunks, spaced 200 feet apart along bank, extending 30 feet out into low-water channel, and pointing slightly downstream. Controls have base width of 11–14 feet and height at outer tip of 11–14.5 feet above stream bed. Tree trunks are securely lashed together with wire and fastened to cast-iron screws sunk to depth of 12–18 feet below stream bed or ground surface. Cost, \$10, per lineal foot of bank, was less than that of any equally satisfactory revetment formerly constructed.—*R. E. Thompson.*

Field Welding Experience on 65-Inch Mokelumne Pipe. ARTHUR P. DAVIS. Eng. News-Rec., 97: 912-4, December 2, 1926. Illustrated description of welding experiences on 65-inch Mokelumne pipe of East Bay Municipal Utility District, California. It was found that use of welded joints in both shop and field for first unit of line, which is 86 miles long, would effect saving of over \$4,000,000, or 30 per cent of contract price, but as previous experience was lacking, provision was made in contract for substitution of riveting at an increase in contract price if welding was not adjudged satisfactory. Increase was to be 40 per cent of difference between welded and riveted pipe. About 26,000 feet of line was connected by butt-welded circumferential joints, but as a considerable percentage of field joints were unsatisfactory and had to be done over, riveted joints were then substituted. The longitudinal electric welds, made under shop conditions, have proved satisfactory. In field welding the oxyacetylene process was used on outside of pipe, an electric arc being used on inside to supplement or "back up" the external weld and to ensure proper fusion of internal edges. Physical and microscopical examinations indicated that electric weld on inside of joints improved the condition of the oxyacetylene weld, having effect of normalizing it and increasing its tensile strength. Oxyacetylene welding, being a rather slow process, caused much expansion of pipe metal and introduced unequal internal stresses in different parts of circumference, sufficient in numerous cases to cause joints to crack open as completed weld cooled. In an extreme instance, in attempting to complete 2-foot length of weld which had unusual width of 1 inch at far end, it was found that before weld had been completed this 1-inch gap had closed up tightly and part of plate had to be cut out before weld could be finished. Another difficulty was due to temperature differences caused by sun, which at times amounted to 80°F. between top and bottom of pipe. Pipe which had been delivered when change was made to riveted joints were lap-welded by means of butt strip placed entirely around joints and welded at both edges inside and out with electric arc. About 1.3 miles were connected in this way with very good results.—R. E. Thompson.

Securing High Early Strengths from Ordinary Portland Cement. H. S. VAN SCOYOC. Cont. Rec., 40: 52, 75-6, 1926. High early strength may be obtained by (1) use of CaCl_2 in proportion of about 2 per cent by weight of the cement; (2) use of low water-cement ratio; (3) placing concrete at temperature as near 70°F. as possible; (4) mixing concrete for at least $2\frac{1}{2}$ minutes after all materials have been added; and (5) curing concrete in a moist atmosphere as near 70°F. as possible. A compressive strength of 2,000 pounds per square inch may be obtained in 24 hours by the use of CaCl_2 . Calcium chloride free from MgO and CaOCl_2 must be employed, and, as the results vary with the chemical and physical characteristics of the cement, tests should be first carried out with the particular brand of cement used.—R. E. Thompson (*Courtesy Chem. Abst.*)

Building Small Concrete-Lined Earth Reservoir. J. P. BAILEY. Eng. News-Rec., 97: 1082-3, December 30, 1926. Illustrated description of construction of 14-m.g. service reservoir in Oneida, N. Y. Reservoir is 230 by

230 feet, with semi-circular ends having radii of 115 feet. Embankment is 20 feet wide at top, with both slopes 1 on 2. Total depth is 19 feet and maximum water depth 16 feet, maintained by notch-shaped overflow channel. Slopes were paved with 6-inch slabs of concrete and bottom with 4-inch slabs, both of 1:2:4 mix. Elastite was used in all joints and all side slabs were finished with 1-inch mortar coat. Total cost was \$65,711.—*R. E. Thompson.*

Removal of Oil from Boiler Feed Water. J. C. DIJXHOORN. Dutch 14,335, February 15, 1926. From Chem. Absts., 20: 1482, May 10, 1926. Filtration of oil-containing feed water through filter press provided with thin layer of aluminum hydroxide (either directly applied or added to water) removes finely emulsified oil completely.—*R. E. Thompson.*

Concrete Arch Bridges Support Clarifier Mechanism. LORENZ G. STRAUB. Eng. News-Rec., 97: 619-20, 1926. Illustrated description of clarifier installation in the new water softening and Fe removal plant in Springfield, Ill., in which, for esthetic reasons, concrete arch structures were adopted in place of the steel bridges usually employed.—*R. E. Thompson (Courtesy Chem. Abst.).*

Progress in the Purification of Water Supplies. NORMAN J. HOWARD. Cont. Rec., 40: 52, 151-5, 143-4, 1926. A review of progress in the treatment of water, including filtration, coagulation, softening, correction of corrosiveness, iodization, and chlorination.—*R. E. Thompson (Courtesy Chem. Abst.).*

Interest During Construction not a Capital Charge for Taxes. Eng. News-Rec., 97: 1085, December 30, 1926. The United States Board of Tax Appeals, in case of Spring Valley Water Co. against Commissioner of Internal Revenue, has ruled that "Interest paid by a water corporation on borrowed funds used in the construction of a dam may not be included in the cost of the dam in determining the amount deductible as a loss upon its destruction." From 1913-1918 the company was engaged in building dam on Calaveras Creek with funds borrowed by it for general corporate purposes. Interest computed monthly, which amounted to \$38,224.51 for years 1913, 1914 and 1915, was deducted from gross income returns and was allowed by the commissioner. On March 24, 1918, a slide occurred at the dam whereby a considerable part was destroyed and lost to company without compensation. In its income tax return for 1918 the company deducted from its gross income the sum of \$460,000, representing alleged loss sustained through destruction of dam. The commissioner, in auditing return, increased net income by the sum of \$38,224.51. disallowing its inclusion in loss.—*R. E. Thompson.*

Factors Other Than Dissolved Oxygen Influencing the Corrosion of Iron Pipes. J. R. BAYLIS. Ind. Eng. Chem., 18: 370-80, 1926. From Chem. Absts., 20: 1381, May 10, 1926. Maximum iron concentrations reached in natural waters containing carbon dioxide and calcium salts are much less than theoretical solubility of ferrous hydroxide. Data on solubility of ferrous carbonate in presence of calcium carbonate given. Continuation of corrosion under rust layers depends on diffusion of soluble iron chlorides and sulfates. Pitting

occurs under breaks in impervious rust membrane. Some iron oxides are magnetic and cling to metal surface.—*R. E. Thompson.*

St. Catharines, Ont., Has Model Water Filtration Plant. ALEX. MILNE. *Cont. Rec.*, 40: 52, 209-11, 1926; 41: 7-13, 1927. The history of the water supply of St. Catharines, derived from Lake Erie via the Welland Canal, is outlined and the new filtration plant is described in detail and illustrated. The plant consists of coagulation basins providing a retention period of 1½ hrs., 12 rapid sand filters, and a clear water basin.—*R. E. Thompson (Courtesy Chem. Abst.).*

Filtration Plant with New Features. *Cont. Rec.*, 40: 879-83, September 15, 1926. Illustrated description of new filtration plant of Metropolitan Water Board of London, England, at Walton, consisting of system of double filtration—rapid sand primary filters and slow sand secondary filters. Apparatus has been provided for treating water with chlorine should this be found necessary. There are 18 rapid sand filters of 1-2 m.g.d. capacity when operated at 100-200 gallons per square foot per hour, and 6 slow sand filters each of an area ½ acre. It is expected that latter will be operated at 300-400 per cent of normal rate for slow sand filters. The rapid sand filters are of two types—supplied by Candy Filter Co., and the Paterson Engineering Co. The former are equipped with an arrangement which automatically closes filtered water outlet when water reaches correct level for washing after raw water has been shut off, and which gradually opens filtered water outlet when washing has been completed. This apparatus and the Module or rate controller, and the Paterson patented filter under-drain system are described in detail and illustrated.—*R. E. Thompson.*

Composition of Imported Bottled Waters. A. E. MIX and J. W. SALE. *J. Am. Med. Assoc.*, 85: 1963-7, 1925. From *Chem. Absts.*, 20: 1481, May 10, 1926. Imported and domestic waters are classified under their predominating mineral constituents as follows: dolomitic limestone, Vichy type, sodium bicarbonate, sodium chloride, magnesium sulfate or sodium sulfate, or both, and iron type. Over 250 imported waters were analyzed and classified.—*R. E. Thompson.*

Two Arch Dams Fail Through Undermining of Abutments. *Eng. News-Rec.*, 97: 616-8, October 14, 1926. Illustrated details given of failure of two similar thin concrete arch dams within past 18 months through destruction of one abutment. One dam was that of Cyanide Gold Mining Co., on Moyie River in Idaho, the other that of Lake Lanier Development Co., Tryon, N. C. In both cases, a very unusual flood overtopped dam and washed out soft rock against which it abutted by first undermining and washing out spillway channel which was put in to protect rock. In second case, failure occurred through simple undermining of cyclopean masonry abutment which had been built at end of dam to replace unsound rock. In both cases the thin concrete arch dam itself withstood the pressure.—*R. E. Thompson.*

Brush, Wire Mesh and Old Rails Make River Retards. Eng. News-Rec., 97: 576-7, October 7, 1926. Brief illustrated description of retards on Fountain River, Pueblo, Col., consisting of old 60-pound rails driven into shale and covered with heavy woven fence wire backed up by brush.—*R. E. Thompson.*

Protections Against River Bank Erosion. A. W. ROGERS. Eng. News-Rec., 97: 1089-90, December 30, 1926. Brief illustrated description of application of protection works similar to that described in previous abstract in the West Indies.—*R. E. Thompson.*

Water Inlet, Screen and Aerator for Liverpool Water Filters. Eng. News-Rec., 97: 539, September 30, 1926. Brief illustrated description of inlets to 3 new slow sand filters at Liverpool, England, which are designed to deliver influent in thin sheet over long weir or as fine spray from orifices in pipe placed above weir. Primary object of aëration is to relieve filters by pre-oxidation of organic matter and to convert ferrous to ferric salts. Untreated water has color of 6.5 "as measured by tintometer," which is reduced to 3.5 by old filters and to 3-3.5 by pre-aëration and new filters. The latter, like the 12 old ones, are 0.8-acre in area and are operated at rate of 2.4 U. S. m.g.d. With one bed out of commission this provides combined capacity of 33.6 U. S. m.g.d., which is about 65 per cent of daily supply.—*R. E. Thompson.*

Portable Apparatus for Determining Residual Chlorine and Turbidity. H. GERSTEIN. Eng. News-Rec., 97: 636, 1926. Brief illustrated description of portable apparatus for comparing unknown turbidity or residual Cl (o-tolidin method) with standards.—*R. E. Thompson (Courtesy Chem. Abst.).*

New Tests for Concrete Workability. Eng. News-Rec., 97: 955, December 9, 1926. Brief description of tests made at Bureau of Standards in coöperation with Celite Products Co. Test experimented with was modification of penetration test developed by the Bureau several years ago.—*R. E. Thompson.*

Inlet Screen and Aerator for Water Filters at Liverpool, England. J. R. DAVIDSON. Eng. News-Rec., 97: 1090, December 30, 1926. Additional information regarding aerators provided in new filters at Liverpool. The spray jets are intended for use in ordinary working, when weather conditions permit. During high winds the water will be delivered in thin sheet, as loss from spray being blown away is considerable. Comparisons of respective efficiencies of the two methods will be made.—*R. E. Thompson.*

22,000 h. p. Hydro-Electric Plant on the Batiscan River. Cont. Rec., 40, 1110-2, November 24, 1926. Brief illustrated description of plant of North Shore Power Co., recently put into service. Dam on Batiscan is approximately 1400 feet long and consists of two earth embankments, one each side of river, three sluiceways each 25 feet wide, and 120 feet of spillway.—*R. E. Thompson.*

How to Measure and Estimate Concrete. Cont. Rec., 40: 904-6, September 22, 1926. Methods adopted as standard by American Concrete Institute are given.—*R. E. Thompson.*

Urges that New York City Go to Housatonic River for Water. Eng. News-Rec., 97: 921-2, December 2, 1926. Brief suggestion by GEO. R. WADLEIGH that Housatonic River should be considered as source of additional supply for New York City, and reply to same by the editor of Eng. News-Rec.—*R. E. Thompson.*

Vertical Butterfly Gates on Exchequer Dam. Eng. News-Rec., 97: 344-5, August 26, 1926. Illustrated description of 168-foot spillways, equipped with 7 vertical-shaft steel gates of butterfly type, at each end of recently completed Exchequer Dam on Merced River in California. The gates, which are 24 feet in length, 14 feet in height and 3 feet in thickness, are operated by two 20-h.p. motors mounted in car which moves along standard-gage track on top of dam.—*R. E. Thompson.*

Crest Gates on Dams. H. K. HIGGINS. Eng. News-Rec., 97: 352, August 26, 1926. Discussion of formula and diagram for weight of crest and head gates for dams and canals given in Eng. News-Rec., 96: 499, March 25, 1926, and revised in Eng. News-Rec., 96: 661, April 22, 1926.—*R. E. Thompson.*

Cost of Pipe Line Excavations. A. T. CUSHING. Eng. News-Rec., 97: 434-5, September 9, 1926. Diagrams given for estimating cost of excavations for pipe lines.—*R. E. Thompson.*

Kansas City Water Tunnel Blast Caused by Natural Gas. Eng. News-Rec., 97: 552-3, September 30, 1926. Findings given of committee of engineers named by city manager of Kansas City to investigate recent explosion in water tunnel under construction. Explosive substance described as "shale gas" and igniting spark is believed to have been from closing of switch to start motor-driven pump or from motor itself.—*R. E. Thompson.*

Water Hammer Not So Important Under Highest Heads. Eng. News-Rec., 97: 577, October 7, 1926. Graph given showing relationship between maximum water hammer and static head, computed from Joukovsky's formula. Pressure rise in penstock with instantaneous stopping of flow in pipe under 2500 feet is less than 100 per cent, whereas with 200-foot head maximum water hammer may be 400-500 per cent of static head and 900 per cent with 100-foot head. Computations made in connection with Buck's Creek plant of Feather River Power Co., in California.—*R. E. Thompson.*

Guniting Upstream Face of Dam as Precaution Against Ice Damage. EUGENE CARROLL. Eng. News-Rec., 97: 432, September 9, 1926. Basin Creek Dam, impounding water supply of Butte, Mont., was originally of monolithic construction with cut stone water face. In 1913 dam was heightened by 13 feet of reinforced concrete, water face being plastered by hand. During

winter, with water level 18-25 feet below crest of dam, ice forming on surface was destructive to plaster face. Joints were repointed with gunite and concrete face given 3 treatments ($1\frac{1}{2}$ inches) of gunite. Previous experiments indicate that gunite will be less liable to injury from ice.—*R. E. Thompson.*

Missouri River Regulation at Lexington Bridge. L. J. SVERDRUP. Eng. News-Rec., 97: 494-5, September 23, 1926. Illustrated description of regulation works on Missouri River consisting of current retards constructed of trees with trunks lashed together in groups and anchored to 15-foot Bignell concrete piles which have average penetration of 60 feet. Majority of retards are 150 feet in length; others are 200-230 feet. Approximately 4750 lineal feet of retards were built at contract price of \$58.50 per foot.—*R. E. Thompson.*

On Computing Shrinkage in Earth-Fill Dams. Eng. News-Rec., 97: 516, September 23, 1926. Discussions of shrinkage in earth-fill dams and its estimation by J. ALBERT HOLMES and FLOYD FERRIS.—*R. E. Thompson.*

Device Guides Torch in Cutting Pipe on True Bevel. Eng. News-Rec., 97: 512, September 23, 1926. Brief illustrated description of adjustable device for holding oxyacetylene torch in position such that when rotated it makes true bevel cut at any desired angle with pipe center line. Apparatus was devised by Hugh F. Brown for use during construction of 26-30-inch steel supply line of Marin Municipal Water District, California. Patent applied for.—*R. E. Thompson.*

Assembled 12-In. Pipe Lowered as Unit in Navigable Waterway. Eng. News-Rec., 97: 514-5, September 23, 1926. Illustrated description of construction of 12-inch distribution main by Spring Valley Water Co., San Francisco, across Islais Creek, a ship channel about 200 feet wide. Depth of water is now only 20 feet, but as 30-foot depth is proposed, a trench 16 feet deep was dredged to provide adequate clearance. Pipe selected was Class B flanged cast-iron with lead packed flexible joints. Bolts were of Tobin bronze and gaskets of sheet lead. Flexible joints, which are of ball-and-socket type with movement of 10° from center line, are special in that lead was poured into sockets and thoroughly hammered to force it slightly into space to be occupied by ball end. Lead filling in sockets and hold-on rings was then machined to exact spherical shape of ball to be fitted. Joints are reported to be absolutely tight under 65 pounds pressure. Pipe was lowered as unit with full pressure of 65 pounds per square inch on line.—*R. E. Thompson.*

Some Fallacies in the Valuation of Water Power. ALTON D. ADAMS. Eng. News-Rec., 97: 470-1, September 16, 1926. Discussion of contentions frequently made in court regarding market value, increased expense, lost water, constant loss, etc., to increase award of damage for water diverted to municipal supply.—*R. E. Thompson.*

Good Chimney-Building Practice. Eng. News-Rec., 97: 471, September 16, 1926. Brief discussion of good practice in chimney construction from article

by D. KNICKERBACKER BOYD in Quarterly of National Fire Protection Association (April, 1926). Employment of standard linings of fire clay reduces exposed mortar joints from 10 to 1.—*R. E. Thompson.*

Hydraulic Data on Rapidly Rising Flood in Small Stream. D. J. F. CALKINS. Eng. News-Rec., 97: 416-7, September 9, 1926. Hydraulic data given on flood on Squillchuck Creek in Washington State.—*R. E. Thompson.*

New Rubber and Fabric Staunching Device for Gates. JULIAN HINDS. Eng. News-Rec., 97: 254-5, August 12, 1926. Illustrated description of staunching device recently developed for radial and Stoney gates by U. S. Bureau of Reclamation. New seal, which promises largely to replace metal staunching rods, split hose, etc., is of rubber and cord fabric construction similar to that used for automobile tires. Application to 20 by 10-foot radial gates of spillway of McKay dam near Pendleton, Ore., and to 20 by 26-foot Stoney gate at inlet to Gurnsey dam in Wyoming illustrated. Specifications included.—*R. E. Thompson.*

Water Service Connection and Meter Rules at Venice, Neb. Eng. News-Rec., 97: 266-7, August 12, 1926. Water supply for summer resort known as Venice is owned and operated by Martin and Heyn Co. First cost of service and meter is borne by consumer. All material and labor required to point 18 inches beyond meter is supplied at uniform rate of \$42.50. Section of regulations governing material for service pipe from meter and to and into building is given. Flat charge of \$6 per year is levied in advance, with additional charge of 20 cents per 1000 gallons less 5 per cent if bill is paid within 10 days.—*R. E. Thompson.*

"Tar Scraper" on Marin Conduit Job Uses Waste Acetylene Gas. Eng. News-Rec., 97: 435, September 9, 1926. Brief illustrated description of tar scraper developed by HUGH F. BROWN to remove protective coating in preparation for making welded joint in 26-inch steel pipe line of Marin Municipal Water District, Calif. Scraper utilizes acetylene from drums in which pressure has been drawn down below that considered satisfactory for welding.—*R. E. Thompson.*

Theoretical Energy Losses in Intersecting Pipe Lines. Eng. News-Rec., 97: 437, September 9, 1926. Discussion of article by J. C. STEVENS (Eng. News-Rec., 97: 140) by HAROLD A. THOMAS and reply to same by J. C. STEVENS.—*R. E. Thompson.*

Endurance Testing of Metals—New Developments. Eng. News-Rec., 97: 332-3, August 26, 1926. Summary of principal results reported to Am. Soc. for Testing Materials of endurance tests of metals, including steels, copper, etc. Fatigue effects of grooves and threads, and effect of water corrosion discussed. Lowering of endurance limit by corrosion ranged for different steels from 3 to 30 per cent for slight corrosion and from 20 to 60 per cent for severe corrosion.—*R. E. Thompson.*

Flush Tunnel for Waste Concrete. WILFRED SCHNARR. *Eng. News-Rec.*, 97: 271, August 12, 1926. Flush tunnel, devised by ALEX. ROBERTSON during construction of extension to Nipigon Powerhouse of Hydro-Electric Power Commission, Ontario, for keeping bottom of pit at foot of concrete shooting tower free from concrete drippings, is described briefly and illustrated.—*R. E. Thompson.*

Factors Governing Air Inlet Valves on Pipe Lines. D. C. HENNY. *Eng. News-Rec.*, 97: 294-7, August 19, 1926. Mathematical discussion. Theoretically, if pipe is truly round and if backfill is well tamped without causing deformation, any ordinary pipe, even if built of thin steel plate, should have abundant strength to resist atmospheric pressure when complete vacuum exists on inside. Pressure then is radially inward and, in case of 24-inch No. 10 gage steel pipe, would stress steel only to 1300 pounds per square inch. It is well known that collapse, when it occurs, is not due to lack of compressive strength in steel of round pipe but to its lack of strength as an arch when deformed and carrying unevenly distributed loads.—*R. E. Thompson.*

Cross-Connections Eliminated at Buffalo. *Eng. News-Rec.*, 97: 259, August 12, 1926. Reported that all cross-connections between city water supply and questionable sources have been eliminated by July 1, in accordance with resolution adopted by New York State Public Health Council. In all cases plants having cross-connections expressed willingness to cooperate when notified.—*R. E. Thompson.*

How Typhoid Was Cut Down at East Liverpool. *Eng. News-Rec.*, 97: 297, August 19, 1926. Water supply is obtained from Ohio River. During 4 years preceding completion of water treatment plant in 1918, average typhoid death rate was over 75 per 100,000. During succeeding 4 years plant was operated under direction of part-time consulting analyst and average typhoid rate was 38 per 100,000. During 3 years ending 1925, with plant operated under direction of full-time chemist-in-charge, only 2 deaths have occurred, one each in 1923 and 1924 and none in 1925. Rate in 1921 was 55.3; 1922, 18.2; 1923, 4.5; 1924, 4.4; and 1925, 0. Estimated population in 1925 was 22,900.—*R. E. Thompson.*

Dam Construction in Winter on the Androscoggin. *Eng. News-Rec.*, 97: 326-331, August 26, 1926. Illustrated description of construction of dam of Gulf Island hydro-electric plant of Central Maine Power Co. Dam is 2600 feet long, 1323 feet being of concrete, maximum section of which is 110 feet high. Dam will form pond about 10 miles long and one mile wide (maximum) holding about 4,000,000,000 cubic feet. No uncommon winter placing methods were employed but common methods were applied thoroughly, which added 12-15 per cent to normal warm weather cost. Concrete left mixer at 80-90° and placed concrete was sheltered with canvas and kept warm by means of steam jets. In first winter's works there was not a fault in concrete due to freezing. Total cost of development will be about \$5,000,000.—*R. E. Thompson.*

Laying 42-In. Concrete-Pipe Sewer on Ocean Bottom. Eng. News-Rec., 97: 292-3, August 19, 1926. Illustrated description of construction of concrete outfall sewer extending 3214 feet into Pacific Ocean, terminating in water depth of 45 feet. Joints first laid were made wholly with asphaltic compound. Later improvement was use of rope of loose strands of oakum coated with liquid bitumastic in conjunction with asphaltic compound which would swell in event of failure of latter. Joints disturbed by earthquake during construction were calked with lead wool, use of 99 per cent wool being found advisable. On last day of construction, 5 sections were laid with diver below only $1\frac{1}{4}$ hours.—*R. E. Thompson.*

Behaviour of Flexible Reinforced-Concrete Mattresses as Bank Protection on Deep Rivers. B. OKAZAKI. Eng. News-Rec., 97: 248-250, August 12, 1926. Data given on flexible reinforced-concrete mattresses as bank protection in lower portion of Ishikari River (one of two largest rivers in Japan, draining 6,000 square miles) where channel depth in front of natural caving bank varies from 25 to 50 feet at low water stage and from 37 to 60 feet in flood time. Total length of protected bank is 35,982 feet. Initial cost is \$6.35 per lineal foot and maintenance cost 15 cents per lineal foot per year. On basis of assumed probable life of 20 years, sum of annual allotment of first cost and maintenance is 46.8 cents per foot. Costs of protection works at mouth of Liao River, involving several mixed systems ofrevetment, given for comparison: initial cost \$20.47, annual repair cost \$1.135 and sum of annual allotment and maintenance \$3.182 per lineal foot. Method of construction described and illustrated. Galvanized wire has been in use as long as 15 years in Japan without suffering appreciably from rusting.—*R. E. Thompson.*

Draft Tube Lined With Cast-Iron at Big Creek No. 8 Plant. Eng. News-Rec., 97: 182-3, July 29, 1926. Brief illustrated description of reconstruction of draft tube of plant of Southern California Edison Co., on San Joaquin River. Lining was constructed of cast-iron, $1\frac{1}{4}$ inches thick, made in 8 sections.—*R. E. Thompson.*

Leakage Tests on Steel Water Mains. Eng. News-Rec., 97: 209, August 5, 1926. Brief data given on results of tests for leakage of 42- to 60-inch Lockbar steel pipe recently laid in Detroit. Arbitrary limit of leakage specified was 1 gallon per day per foot of pipe regardless of diameter, equivalent to 88,110 and 126 gallons per day per inch diameter per mile of pipe for 60-, 48- and 42-inch pipe respectively.—*R. E. Thompson.*

Boiler Compound. W. P. PECK, U. S. 1,579,949, April 6. From Chem. Abst., 20: 1679, May 20, 1926. Boiler cleaning mixture is formed from extract of hemlock 40 pounds, sodium carbonate 60 pounds, brown sugar, 10 pounds, and water 30 gallons.—*R. E. Thompson.*

Keeping Salt Water Out of Lock-Controlled Waterways. W. M. MEACHAM. Eng. News-Rec., 97: 219-20, August 5, 1926. Conclusions derived from study to determine cause of salt contamination of water in Lake Washington Ship

Canal at Seattle given, together with plans for exclusion of salt water. Presence of salt renders water unfit for use as supply for domestic and boiler purposes. Chemical diffusion of salt upward through body of fresh water is so slow that it is negligible. Mechanical diffusion, including mixing due to convection currents, is material factor.—*R. E. Thompson.*

Experimental Deformation of a Cylindrical Arched Dam. B. A. SMITH. *Proc. Am. Soc. Civ. Eng.*, 52: 8, 1596-1601, October, 1926. This paper gives experimental confirmation of the author's formulas on arched dams.—*John R. Baylis.*

Venturi Tube Characteristics. J. W. LEDOUX. *Proc. Am. Soc. Civ. Eng.*, 52: 9, 1787-96, November, 1926. Author discusses the Venturi tube and gives coefficients of discharge and losses of head determined from a series of tests. Nineteen tubes ranging in size from 30-inch to 1-inch were used. Effects of angles of convergence and divergence, of tube ratios, and of size of tubes on coefficient of discharge and on loss of head, are discussed. Conclusion is reached that for Venturi tubes ranging in size from 4 to 30 inches, the coefficient of discharge is approximately the same and ranges from 0.96 to 0.985, with an average of about 0.977, for high velocities, and from 0.90 to 0.94 for low velocities. Opinion is given that Venturi tube is only surpassed in accuracy by actual weighing or volumetric measurements. A V-notch or rectangular weir is excellent for approximate measurements, but is not sufficiently accurate for checking a well-designed Venturi tube.—*John R. Baylis.*

Storage Required for the Regulation of Stream Flow. CHARLES E. SUDLER. *Proc. Am. Soc. Civ. Eng.*, 52: 10, 1917-55, December, 1926. This paper presents a study followed by a set of curves for determining the dependable stream flow to be expected due to a given reservoir capacity. The author finds that Hazen's "seasonal storage curves" can be depended upon, and has developed extensions to them. Consideration is also given to those factors due to which a reservoir located on a tributary, or at a point some distance up stream from the point of use, may be less useful than one having a point of use corresponding with the dam site. A series of curves for predicting the dependable flow at the point of use are given. A number of computations are made, assuming storage capacities and rates of use as determined by the diagrams, and applying them to various streams for which flow records covering a period of years were available.—*John R. Baylis.*

Water Analysis Conversion Factors. Anon. *Ry. Rev.*, 79: 18, 662, 1926.—*R. C. Bardwell (Courtesy Chem. Abst.).*

Excelsior Filters for Water Treating Plants. W. M. BARR. *Ry. Engineering and Maintenance*, 23: 1, 28-29, and 2, 45. BARR is convinced that excelsior filters are the most satisfactory filtration medium for railroad water treating plants, although this fact is disputed by others.—*R. C. Bardwell (Courtesy Chem. Abst.).*

Sand versus Excelsior Filters. C. R. KNOWLES. Ry. Engineering and Maintenance, 23: 3, 90, 1927. Experience on Ill. Cent. R. R. indicates sand superior to excelsior as a filtration medium.—R. C. Bardwell (Courtesy Chem. Abst.).

Sludge Remover for Locomotive Boilers. Anon. Ry. Age, 81: 25, 1230, 1926. New device consists of operating rod connected to double blow off cocks with slotted copper pipes in water legs.—R. C. Bardwell (Courtesy Chem. Abst.).

Norfolk and Western Builds Large Water Treating Plant. Anon. Ry. Rev., 79: 16, 609-610, 1926. The Norfolk and Western Ry. has completed final units of a 5,400,000-gallon per day softening plant at their Roanoke, Va., terminal. Water is pumped from the Roanoke River to a 2,000,000-gallon concrete sedimentation basin where alum coagulation and chlorine treatments are given. The softening plant consists of two units, each of 125,000 gallons per hour capacity with steel tanks 50 feet and 55 feet diameter by 35 feet high with excelsior filters at the top. Chemical proportioning device is of the tipping bucket type. Normal hardness of raw water is 10 grains per gallon in addition to which 1,000 tons of mud are removed annually. Clear water storage facilities consist of one 200,000-gallon concrete and one 400,000-gallon steel elevated tank. Saving from purification is estimated at \$250,000 per year.—R. C. Bardwell (Courtesy Chem. Abst.).

Southern Pacific Softens Water by Zeolite Method. C. W. STURDEVANT. Ry. Age, 81: 15, 675-676; Ry. Rev., 79: 15, 537-538, 1926. The Southern Pacific R. R. has nine zeolite plants in operation and five more under construction. Advantage of system lies in automatic proper chemical proportioning and low cost of operation where NaCl is available at reasonable rate. Regeneration requires $\frac{1}{2}$ pound NaCl per grain of hardness per gallon for every 1,000 gallons treated. Waters treated vary from 11 to 34 grains per gallon incrusting matter. Some foaming trouble has been experienced. No evidence has occurred as yet of corrosion from treated water or of caustic embrittlement. Marked reduction in cost of boiler maintenance has been made.—R. C. Bardwell (Courtesy Chem. Abst.).

A Profitable Investment. Editorial. Ry. Rev., 79: 15, 546, 1926. By volume and weight, the water consumed annually on railroads exceeds all other material. Statistics indicate that over 100,000,000 lbs. of scale forming matter is removed annually at 1,200 softening plants effecting remarkable savings.—R. C. Bardwell (Courtesy Chem. Abst.).

Fuel Consumption Cut Seventeen Per Cent. Ry. Rev., 79: 14, 491-495, 1926. Installation of the Dabeg feedwater heater on the Delaware and Hudson effected a saving of 17 per cent in locomotive fuel. This type is in use and was developed on the Austrian Federal Railways. It is a combination open type pre-heater with automatic boiler feed pump. Complete test statistics and installation diagram are shown.—R. C. Bardwell (Courtesy Chem. Abst.).

Pitting of Locomotive Boilers. W. A. POWNALL. Ry. Rev., 79: 8, 263-270, 1926. Causes assigned as contributing to pitting are: stopped up flues; mud and scale in barrel of boiler; poor circulation; trapping of O_2 and CO_2 ; rusting of boiler material before used in boilers; acid water; salt water; organic matter; and any chemical condition whatever of feed water that increases the electrical potential difference between boiler metal and water. Remedies offered are: use of corrosion resistant materials; maintenance of proper caustic alkalinity in boiler water: avoidance of high salt, iron, and acid waters; improved circulation; thorough boiler washing; rejection of rusted material; and avoidance of cinder accumulation against flue sheet or in flues.—R. C. Bardwell (*Courtesy Chem. Abst.*).

Corrosion an Electro-Chemical Phenomenon. L. O. GUNDERSON. Ry. Rev., 79: 10, 335-343, 1926. Review of theory with emphasis on electrochemical and special attention to thermal electrolytic effect. To inhibit corrosion, the H-ion concentration should be reduced to a minimum and O_2 removed from the water, or anti-corrosive influences established adjacent to interior boiler surfaces by electrical means. Experiments indicate that thin coating of arsenic on boiler metal will afford protection. Experiments are being conducted in yard engine and passenger locomotive with the electrolytic system. Installation diagram for electrolytic polarization system is shown.—R. C. Bardwell (*Courtesy Chem. Abst.*).

Embrittlement of Boiler Plate. Anon. Ry. Rev., 79: 17, 619-624, 1926. Detailed abstract of report by S. W. PARR and F. G. STAUB at A. S. T. M. 1926 convention.—R. C. Bardwell (*Courtesy Chem. Abst.*).

How Wrought Iron is Manufactured. CHARLES T. RESSLER. Ry. Rev., 78: 24, 1075-1077, 1926.—R. C. Bardwell (*Courtesy Chem. Abst.*).

Regulations of Federal and State Authorities Pertaining to Drinking Water Supplies and Sanitary Examinations of Drinking Water Supplies. Com. Rep. Amer. Ry. Engr. Assoc., 28: Bull. 292, 225-226. Progress report.—R. C. Bardwell (*Courtesy Chem. Abst.*).

Pitting and Corrosion of Boiler Tubes and Sheets. Taking into Consideration Character of Metal Used, Method of Manufacture, Construction of Boilers, and Quality of Water. Com. Rep. Amer. Ry. Engr. Assoc., 28: Bull. 292, 226-227. Progress report mentions test being made on O_2 removal with open type feed water heater.—R. C. Bardwell (*Courtesy Chem. Abst.*).

Cost of Impurities in Locomotive Water Supply and the Value of Water Treatment. Com. Rep. Amer. Ry. Engr. Assoc., 28: Bull. 292, 227-229. Progress report.—R. C. Bardwell (*Courtesy Chem. Abst.*).

NEW BOOKS

La Concentration en Ions Hydrogène de l'Eau de Mer. R. LEGENDRE. Paris: Les Presses Universitaires de France. 287 pp. Fr. 30. From Chem. Abst., 20: 1025, April 10, 1926.—*R. E. Thompson.*

Water Sterilization by Gaseous Chlorine. London: The Paterson Engineering Co., Ltd. From Chem. Abst., 20: 1126, April 10, 1926.—*R. E. Thompson.*

Die Mineralquellen und Kurmittel des Iodbades Tölz mit besonderer Berücksichtigung ihrer Anwendungsweise. EMIL MORGENSTERN. 5th edition, revised and enlarged. Bad Salzungen; L. Scheermesser. 91 pp. R.M. 1.50. From Chem. Abst., 20: 1292, April 20, 1926.—*R. E. Thompson.*

The Colorado River Compact. REUEL LESLIE OLSON. Cloth; 6 x 10 inches; pp. 527. \$8, from author. Reviewed in Eng. News-Rec., 97: 472, September 16, 1926.—*R. E. Thompson.*

Der Genauigkeitsgrad von Flügelmessungen bei Wasserkraftanlagen. A. STAUS. Berlin: Julius Springer. Paper; 6 x 9 inches; pp. 35. 2.4 reichmarks in Germany. Reviewed in Eng. News-Rec., 97: 840, November 18, 1926.—*R. E. Thompson.*

Waterworks Administration: Being a Practical Guide to the Solution of the Many Problems to be met with in the Business Management of a Public Water Supply Undertaking, and Containing Some Suggestions for the Amendment of Waterworks Law. W. H. PARSONS. London: P. S. King & Son, Ltd. Cloth; 6 x 9 inches; pp. 309. 18s. Reviewed in Eng. News-Rec., 97: 841, November 18, 1926.—*R. E. Thompson.*

Steam Turbines. GIUSEPPE BELLUZZO. Translated by A. G. BREMNER. London: Charles Griffin & Co., Ltd., Philadelphia: J. B. Lippincott Co. Cloth; 6 x 9 inches; pp. 732. \$17.50. Reviewed in Eng. News-Rec., 97: 842, November 18, 1926.—*R. E. Thompson.*

Guiding Principles of Public Service Regulation, Volume 3. HENRY C. SPURR. Public Utilities Reports, Inc. Drawing from his extended experience as editor of "Public Utilities Reports" and his familiarity with cases in which public utility matters are involved before courts and commissions, the author has rearranged and amplified the series of editorials that have been appearing currently during the past year in the advance sheets of P.U.R., and has worked them into 865 pages and 26 chapters, covering in a comprehensive way the guiding principles on Return, Cost Factors, and Rate Schedules laid down by our regulatory and judicial bodies. Almost 4000 cases are cited, involving every kind of utility service, and are so referenced as to be made readily accessible. The plan of the book follows that of the first and second volumes, previously issued, wherein questions of valuation and of service were discussed.

The return to which utilities are entitled and that below which confiscation would take place must be determined, as the author develops, in the light of

what is a fair and reasonable return. There is a discussion of what return is required to attract capital, and of what weight has been given, in fixing a rate of return, to the efficiency of management, the character of service, the development of the property, the trend of prices, and other elements affecting the particular utility under review. Between the limits of confiscation and of the worth of the service, regulatory bodies have moved rather freely, with slight interference from the judiciary. It is not surprising, therefore, that the rate of return allowed has varied over a wide range, although of late it has had a tendency to settle down between 7 and 8 per cent.

The cost basis of rate making is elaborated upon and its ramifications developed. The allocation of cost is susceptible of resolution into broad principles only with difficulty, but a number of cases cited indicate the tendency in certain jurisdictions.

It is evident that of recent years guiding principles have become more pronounced, and a tendency evidenced to follow precedent, except where the individualities of any case dictate otherwise. The well established rule that property cannot be taken away without just compensation has been made to apply to the use of property and earnings therefrom. The line between regulation and management is not so clearly drawn, but commissions very generally have evidenced respect for it. No acceptable method of rewarding efficient and penalizing inefficient management has been worked out. The rate of return is the only effective instrument so far devised, although the gradual shortening of the range of variation of this factor is tending to limit its usefulness.

The practice in different jurisdictions as to the filing and publishing of rate schedules, as to their form and designation, and as to their interpretation, application, and duration is set out in the chapter on Rate Schedules. While this cannot be other than indicative only, nevertheless it may be helpful in avoiding certain pitfalls. The status of municipal contracts is of interest, especially in view of the effect of the adoption of regulatory laws.

Rates and rate schedules, flat versus meter rates, the minimum charge, the service charge, the demand charge, quantity rates, and contract rates are discussed in separate chapters. The factors to be considered in rate making, including among others the cost of service, the value of service, the economic limit, the ability of customers to pay, the effect of competition, and the usefulness of comparisons are outlined in a chapter preparatory to a series of seven chapters dealing with the rates of particular kinds of utilities.

The chapter on water rates throws much light on the way in which state commissions have been apportioning charges and the consideration they have given to the demand factor, use factor, investment, and expenses, in deciding upon rates for public and private fire protection and for domestic, commercial and industrial consumption. One section also deals with irrigation rates and another with incidental questions interesting every water works manager, such as connection charges, meter replacement charges, and charges for seasonal business.

This third volume takes its place alongside the first two and will doubtless be followed by others dealing with additional vexatious and contentious utility problems, the set forming a valuable reference work on "Guiding Principles of Public Service Regulation."—*H. Carl Wolf.*

SOCIETY AFFAIRS

INDIANA SECTION

On February 17 and 18, 1927 the Indiana Section held its annual meeting at the Claypool Hotel, Indianapolis, Ind. About two hundred men attended.

In the absence of Senator Bradford, Dr. W. F. King discussed the Izaak Walton League in its relation to stream pollution. He also reported on the Cooperative Survey of White River carried on by the Indianapolis Water Company, the Indiana State Board of Health, the Conservation Department and the Indianapolis Sanitary District.

J. K. Hoskins gave a summary of the findings of the survey of the southern end of Lake Michigan showing how pollution has increased and the effect of construction in that district on the direction of waste flows.

The Economic and Sanitary Aspects of Sewage Treatment as against Water Purification were considered by Paul Hansen. In the development of his subject he warned against dogmatic emphasis of either, suggesting that individual situations should be governed by factors peculiar to each.

John W. Moore, who has developed well water supplies in Indiana for a number of years, talked on the Economic Limit to Deep Well Production.

The water cement ratio control in concrete pouring was reported as being entirely feasible in construction by W. C. Mabey, who described concrete handling methods employed in the construction of a reservoir for the Indianapolis Water Company. The contractor found it an agreeable method of control and the resulting work was found to be of high quality.

For several years, fire protection has received close attention from the water works men. At this meeting George W. Booth and Alfred M. Hogston spoke on this subject.

Charles Brossman described novel design features of the new intake at Michigan City, showing how certain construction difficulties were overcome.

Appraisal methods are of vital interest to water supply men. H. O. Garman, formerly Engineer for the Indiana Public Service Commission, read a paper on this subject.

Joseph J. Daniels, Attorney for the Indianapolis Water Company, presented the most important features of their rate case and the United States Supreme Court decision. This case has been considered very important to public utilities.

W. H. Durbin could not be present, but his paper was read. By intensive and novel advertising, and a liberal financing plan, plumbing fixtures were placed in many houses, thereby increasing customers.

L. S. Finch, Director of the State Water and Sewage Department, presented a scheme for the classification and rating of water supplies based on physical surveys and laboratory examinations.

Though the cross connection evil has been fought for many years and some states have prohibited certain types, the subject is still of great interest and importance from a public health standpoint. A. E. Gorman gave an account of a campaign against them in Chicago.

Flood prevention was the topic of a large part of one session. C. S. Bennett, of the Miami Conservancy District, Dayton, Ohio, described some of the engineering features and data of design and outlined the method of operation.

C. C. Oberleas gave an outline of the flood prevention program planned for Indianapolis.

A resolution approving the formation of a sewage and waste treatment division of the American Water Works Association was passed by the Section. It was felt by the members that a desirable cooperation between the water and sewage men could be fostered in this way.

John W. Moore was elected president, C. E. Stewart, vice-president, and C. K. Calvert, secretary-treasurer.

C. K. CALVERT,
Secretary-Treasurer.

CANADIAN SECTION

The seventh annual meeting of the Canadian Section was held in Ottawa from Wednesday, March 2, to Friday, March 4, 1927, with headquarters at the Chateau Laurier.

The convention was the most successful in the history of the

Canadian Section and the attendance was the largest on record. It was distributed as follows:

Active members.....	73	
Guests, actively interested in the management of water works, or chairmen or members of water boards, commissions, etc.....	68	
Associate members.....	58	199
Ladies.....	11	210

The program for the entire three days was carried out exactly as arranged, and, to show the interest of the members, there were at least forty present in the session room when the convention closed at 5.15 p.m. on Friday.

The convention opened on Wednesday at 9:30 a.m. with registration. Most of the morning was spent renewing old acquaintanceships and inspecting the interesting display of the Canadian Water Works Equipment Association in the Loge and Ball Rooms, which adjoined the meeting room. There were thirty-four exhibitors who showed and explained their supplies and their display was an instructive feature of the convention.

At noon, an informal luncheon was held in the Chateau Laurier. One hundred and sixty members and guests were present to hear Major Walter Blue, of the Gatineau Power Company, describe their extensive hydro-electric development works on the Gatineau River at Chelsea and Farmers Rapids, about twelve miles from Ottawa, which the members were to inspect the following day.

In the afternoon, papers were read by N. J. Howard, on "Some New Aspects of the Treatment of Water with Chlorine," and by A. D. Stalker, on "A Water Waste Survey." Both papers provided considerable discussion, and all members were encouraged to exchange their views on these subjects, so as to give each other the benefits of their practice and experience.

The Secretary of The Association, B. C. Little, took part in the discussion and expressed his pleasure in attending the annual meeting of the Canadian Section.

The ladies visited the House of Parliament in the afternoon and in the evening enjoyed a theatre party, given with the compliments of the Canadian Water Works Equipment Association.

In the evening, two papers were read, one by C. D. Brown, on "Office Records," and the other by Theo. J. Lafreniere, on "The Control of Water Purification Plants."

At 10:30 p.m., the members were taken in motor busses to the Highlea Club on the Quebec side of the Ottawa River, where a supper and entertainment were provided by the Canadian Water Works Equipment Association. Mr. Theo. Lanctot, the City Engineer of Hull, who was a member of the Local Committee, arranged all the details and all agreed that a more amusing and enjoyable evening's entertainment had never been provided at the annual meetings of the Canadian Section.

On Thursday, March 3, the annual business meeting was held at 9:30, and the usual proceedings, such as the appointment of Nomination and Resolution Committees, Scrutineers, reports of Membership and Hose Thread Committees, election of officers and selection of place of next annual meeting, were transacted.

The Scrutineers reported that the new officers elected for the year 1927, were as follows: Chairman, D. McL. Hanna; Vice-Chairman, J. O. Meadows; Trustee, W. E. MacDonald.

The Manufacturers reported that J. J. Salmond, was elected as their representative on the Executive Committee. The Secretary-Treasurer, elected by the Executive Committee, was A. U. Sanderson.

The remaining officers of the Executive Committee are: Trustee, W. C. Miller; Trustee, Marcel Pequegnat; Immediate Past Chairman; R. H. Starr.

London, Ontario, was selected as the place of the next annual meeting, and the question of the Standardization of Hose Threads was referred to a committee consisting of the Chairman of the Canadian Section, the Fire Marshals of the various provinces, a representative of the Dominion Fire Chiefs Association, a representative of the Canadian Standards Committee and a representative of each Section of the Fire Underwriters Association of Canada.

The Nominating Committee selected for the nomination of officers for the year 1928 were: Chester Smith, J. Clark Keith and Harry Carmichael.

The Treasurer reported that the finances of the Section were in excellent condition and stated that there was a balance of \$269.00 in the bank. The auditors, N. R. Wilson and R. L. Dobbin, reported that the financial statement of the treasurer had been audited and found correct.

The Chairman regretted that the President of The Association, Allan W. Cuddeback, could not be present, but was glad to welcome B. C. Little, the Secretary, and C. R. Wood, B. B. Hodgman and John S. Ward of the Manufacturers Association.

On Thursday afternoon, the members and guests were taken by motor bus over a snow dragged highway in Quebec, a distance of twelve miles, to inspect the Hydro-Electric Development of the International Paper Company at Chelsea and Farmers Rapids. A construction train was also used to transport the members between the two large works, where 290,000 h. p. will ultimately be developed. The large dams, spillways, intakes and turbines under construction and partly in operation were viewed with interest by everyone.

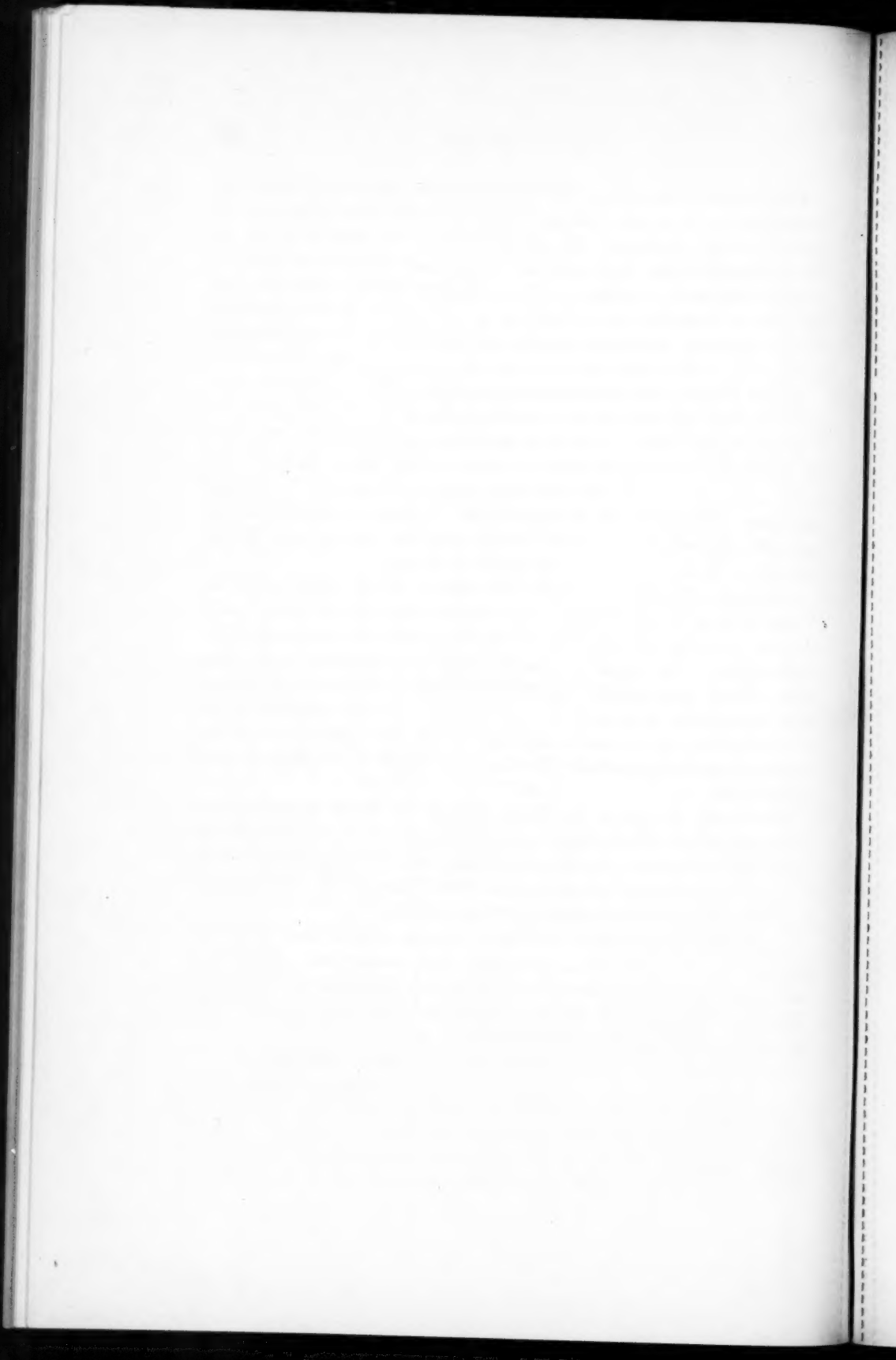
In the evening, the annual dinner was held at the Chateau Laurier, and over 200 listened to an excellent address by Paul Hansen, on "Water Purification." The members were indebted to Mr. Hansen for coming such a long distance to speak at this dinner and speeches were also given by His Worship, Mayor Balharrie, Controller McElroy of Ottawa and William Gore. A splendid entertainment was also provided by certain artists with the compliments of the Canadian Water Works Equipment Association.

On Friday, March 4, a paper was read by W. E. MacDonald, on "The Ottawa Water Works," after which the members were taken by motor bus to visit a section of the Ottawa water works on Lemieux Island. The repair and meter shops and the store yards were also viewed with interest by the members. The pumping station was beautifully decorated for the occasion and the officials of the Ottawa water works were complimented on the appearance of the building and equipment and the excellent manner in which they were maintained.

On Friday afternoon, the ladies visited the Royal Mint and the Canadian National Gallery, while the members assembled for the last session. After C. R. Wood had said a few words to the members, a paper was read on "Water Rates" by J. Clark Keith, and a paper on "Fire Protection Charges" by R. L. Dobbin.

These two papers were discussed at some length, and, after the Resolution Committee had presented their resolutions, which were unanimously adopted, and a vote of thanks and appreciation to the Retiring Chairman, R. H. Starr of Orillia, had been adopted, the seventh annual meeting closed at 5.15 p.m.

A. U. SANDERSON,
Secretary-Treasurer.



**APPLICATION FOR MEMBERSHIP
IN THE
AMERICAN WATER WORKS ASSOCIATION**

Date:.....

.....hereby make application for.....

Membership in the American Water Works Association, and enclose herewith the
sum of.....Dollars, the required initiation fee
and one year's dues in advance.

Name.....

Title or Business.....

Address.....

Business or Professional Experience.....

Recommended by.....

Recommended by.....

Send application to American Water Works Assn., 170 Broadway, New York, N. Y.

(To fill in blank see extracts from the Constitution on other side)

REPORT OF MEMBERSHIP COMMITTEE

We have investigated the qualifications of the applicant, and approve his
admission to.....membership.

Date:.....Chairman

Date:.....

Date:.....

ARTICLE III. OF CONSTITUTION

Section 3. An Active Member shall be either a superintendent, manager or other officer of a municipal or private water works; a civil, mechanical, hydraulic or sanitary engineer, chemist or bacteriologist, including those acting technically as such for, and employed by, Associate Members of the Association; or any qualified person engaged in the advancement of knowledge relating to water supply in general. (Initiation Fee, \$5.00; Annual Dues, \$10.00.)

Section 4. A Corporate Member shall be a water board, water commission, water department, water company or corporation; national, state or district board of health or other body, corporation or organization interested or engaged in public water supply work, and shall be entitled to one representative whose name shall appear on the roll of members and may be changed at the convenience or pleasure of the represented Corporate Member upon written request to the Secretary, and who shall have all of the rights and privileges of an Active Member. (Initiation Fee, \$10.00; Annual Dues, \$15.00.)

Section 5. An Associate Member shall be either a person, firm or corporation, engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works. An Associate Membership shall entitle the holder to be represented by one person on the floor at each meeting but such representative shall not be entitled to vote nor take part in any discussion unless permission is given by unanimous consent of the members present. (Initiation Fee, \$10.00; Annual Dues, \$25.00.)

Membership in the Association carries also membership in its Local Sections, and the Journal, a monthly publication devoted to water works interest. The proceedings of the annual conventions and of the meetings of the Local Sections are published in the Journal, which also contains contributed articles on subjects pertaining to public water supplies.

ORDER BLANK

MANUAL OF WATER WORKS PRACTICE

The American Water Works Association
170 Broadway, New York, N. Y.

Please send me copy or copies of the Manual of Water
Works Practice, for which I am enclosing Five Dollars for each
copy.

Name.....

Address.....

described
-mark

color

Water: 1.25 liter, for 1000 ml of the solution. The solution is clear, colorless, and has a pH of 7.0. The solution is stable for 24 hours at room temperature.

150 mg of the solution is added to 100 ml of water.

The solution is added to 100 ml of water.

MINIAT OF WATER SOLUTION

ORDER 111111

SUBJECT INDEX

- Abutment; repairing, 474 seq.
- Accounting; pipe laying and, 368 seq.
 see Billing
- Aeration; carbon dioxide and, 72
 hydraulic jump and, 26
 solid stream, 539
 spray nozzle, 70
- Agitating device; hydraulic jump;
 1 seq., 422 seq.
 loss of head and, 16
 mechanical, 71
 see Stirrer
- Agitation; with compressed air, 432
 see Mixing basin
- Air compressor; explosions, pre-
 cautions, 468 seq.
- Air lift; *see* Well
- Akron, O.; consumption, 197
 typhoid, 764 seq.
- Alachua, Fla.; water supply, 47
- Albany, N. Y.; consumption, 197
 typhoid, 761 seq.
- Algae; basins, covering and, 343
 birds and, 250
 chlorination and, 444 seq.
 copper sulfate and, 444
 hardness and, 251
 lime treatment and, 259, 446 seq.
 mosquitoes and, 35
 odor and, 444
 oxygen and, 249
 secondary growths, 453 seq.
 see Microscopic Organisms
- Alhambra, Cal.; consumption; meter-
 ing, 200
- Alkalinity; H-ion concentration and,
 573 seq.
 temperature and, 571 seq.
- Alton, Fla.; water supply, 47
- Altoona, Pa.; consumption, 197
- Aluminum sulfate; boiler foaming
 and, 172
 handling, 421 seq.
 see Coagulation
- American Committee on Electrolysis;
 report, 563
- American Medical Association;
 typhoid survey, 760 seq.
- American Society of Mechanical
 Engineers; boiler feed, sodium
 carbonate-sulfate ratio, 156
- American Water Works Association;
 abstracts, 598
 committees; boiler feed studies,
 status, 597 seq.
 standpipes, personnel, 595
 steel pipe, personnel and pro-
 gram, 595 seq.
 water analysis, work, status,
 596 seq.
 manual, status, 598 seq.
 sewage division, resolutions re,
 612, 788
- Standardization Council, report,
 595 seq.
 see Committee Reports; Society
 Affairs
- Ammonia; applying to water, 349
 chlorination, taste and, 241 seq.,
 341 seq.
 excretion of, 392
 see Water Analysis
- Ammonium chloride; chlorination,
 taste and, 235 seq.
- Anopholes; distinguishing, 33 seq.
 malaria and, 483 seq.
 see Reservoir
- Apalachicola, Fla.; water supply, 47
- Apopka, Fla.; water supply, 47
- Arcadia, Fla.; water supply, 48
- Archer, Fla.; water supply, 47
- Arkansas; water supplies, quality,
 261 seq.
- Ashland, Ky.; billing; meter reading,
 694
- Atlanta, Ga.; consumption; 197
 metering and, 463
 meter reading and billing, 694 seq.
 typhoid, 763 seq.
- Atlantic City, N. J.; deLavaud pipe,
 224
- Auburndale, Fla.; water supply, 47
- Avon Park, Fla.; water supply, 47
- Babcock and Wilcox Co.; boiler
 embrittlement study, 182 seq.
- Bacteria, spore-forming;
 bibliography, 594
 bile and brilliant green bile and,
 113 seq.
 chlorination and, 593
 copper sulfate and, 593

- isolation, 592
- water analysis, significance, 115 seq.
- Bacterium coli*; birds and, 250
- H-ion concentration and, 759
- lime treatment and, 259, 759
- purification, limit for, 59 seq.
- reservoir, water level and, 701
- Bacterium coli* test; bile; 113 seq., 116 seq., 594
- pH and, 117
- brilliant green bile study, 112 seq., 115, 117 seq.
- spore formers and; 115 seq., 591 seq.
- bibliography, 594
- brilliant green and, 113 seq.
- Bagdad, Fla.; water supply, 47
- Baltimore, Md.; billing, 697
- coagulation, 717 seq.
- consumption; 199, 244
- metering, and, 463
- filtration, 712 seq.
- typhoid, 763 seq.
- Bartow, Fla.; water supply, 47
- Basin Creek Dam; 374 seq.
- Batesville, Ind.; water supply, 331
- Bay City, Mich.; chlorophenol taste, superchlorination and, 336 seq.
- Beaumont, Tex.; consumption, 197
- Bellair, Fla.; water supply, 47
- Bellview, Fla.; water supply, 46
- Belmont, Mass.; deLavaud pipe, 221 seq.
- Belvedere Water Corporation, Cal.; consumption; metering, 200
- Benson, Neb.; consumption, 198
- Berlin, Ger.; typhoid, 770
- Bernouilli's Theorem; 13 seq.
- Billing; accounting, stub and historic record, 697
- complaints and, 98 seq.
- continuous vs. periodic, 683 seq.
- errors, eliminating, 693
- practice, 689 seq.
- Binghampton, N. Y.; consumption, 197
- Bird; algae and, 250
- pollution and, 250
- scaring by shooting, 250 seq.
- tanks, elevated, discouraging, 294
- see Sea Gull; Swallow; etc.
- Birmingham, Ala.; typhoid, 764 seq.
- Birmingham, Eng.; typhoid, 770
- Blountstown, Fla.; water supply, 47
- Blue Springs; flow, 45
- Boca Raton, Fla.; water supply, 41, 46
- Boiler; water, pH determination, potentiometric, 569 seq.
- Boiler corrosion; embrittlement; bibliography, 188
- calcium chloride and, 180
- calcium nitrate and, 175
- conductivity and, 179 seq.
- hydrogen and, 176 seq., 182, 187 seq.
- joints and, 179 seq.
- loss of, 179
- magnesium chloride and, 180
- oxygen and, 182
- pressure and, 181
- service, continuity and, 179, 181
- sodium bicarbonate and, 175
- sodium carbonate and, 174 seq.
- sodium carbonate-sulfate ratio, 156 seq., 175, 177
- sodium hydrate and, 174 seq.
- steel; iron sulfide in and, 176, 178
- oxide in and, 178
- oxide coating and, 182
- stress and, 175 seq.
- oil waste and, 192
- Boiler feed water: committee work, status, 597 seq.
- foaming test, 168 seq.
- lime treatment and, 191
- oil waste and, 192
- steel mill waste and, 191
- sulfuric acid treatment, and, 191
- treatment; control, pH vs. alkalinity, 570 seq.
- initial, pH control, 582
- lime-soda; continuous vs. intermittent, 152 seq.
- and evaporators, 158 seq.
- and zeolite, 155 seq.
- zeolite; phosphoric and sulfuric acid treatment and, 157
- sodium carbonate and, 156 seq.
- see Boiler corrosion; Boiler foaming; Railroad supplies; Softening
- Boiler foaming; causes, 162 seq.
- lime soda, excess and, 754
- oil waste and, 192
- organic matter and, 168, 172
- phenomena, 161 seq.
- prevention; alum and, 172
- castor oil and, 171 seq.
- pine tar oil and, 172
- smoothness of boiling and, 162 seq.
- sodium carbonate and, 156
- sodium salts and; 163 seq.
- solid matter and, 163 seq.
- superheating and, 169 seq.
- surface concentration and, 164 seq.
- surface layer and, 165 seq.
- surface tension and, 164
- theory, physico-chemical, 164 seq.

- Bond; *see* Financing
- Bonifay, Fla.; water supply, 38, 47
- Boston, Mass.; consumption, 197, 244
typhoid, 761 seq.
- Bourbon, Ind.; well, water level drop, 329
- Bowling Green, Fla.; water supply, 47
- Boynton, Fla.; water supply, 46
- Bradenton, Fla.; water supply, 43, 46
- Brantford, Ont.; fire protection charges, 653
taxation, 665
- Brewster, Fla.; water supply, 47
- Bridgeport, Conn.; typhoid, 761 seq.
- Brilliant green; *see* Bacterium coli test
- Bristol, Tenn.; water supply, 747
- Brockton, Mass.; consumption, 197
- Brooksville, Fla.; water supply, 47
- Buffalo, N. Y.; consumption, 199, 244, 282, 285
filter plant cost, 290
fire protection system, 287 seq.
main cleaning, 287
metering, 285, 314
pitometer survey, 285, 314
pumping, efficiency, 286
rates, 288
typhoid, 762 seq.
waste reduction, 284 seq.
water works; 279 seq.
investment in, 290
- Buffering; Cambridge, Mass., supply, 572
- Bunnell, Fla.; water supply, 47
- Burlington, Ia.; *see* Citizens Water Co.
- Bushnell, Fla.; water supply, 47
- Butler, Ind.; well, water level drop, 329
- Butte Water Co., Mont.; consumption, 384
free service, 385
metering, 384
water works, 371 seq.
- Calcium chloride; boiler corrosion and, 180
conductivity; solubility, 180
- Calcium hydroxide; *see* Lime treatment
- Calcium nitrate; boiler embrittlement and, 175
- California Section; meeting, 263 seq.
- Callahan, Fla.; water supply, 48
- Calomel electrode; *see* Water analysis
- Cambridge, Mass.; buffering, 572
typhoid, 760 seq.
- Camden, N. J.; typhoid, 762 seq.
- Canadian Section; meeting, 788 seq.
- Canton, O.; consumption, 197
typhoid, 764 seq.
- Carbon dioxide; aeration and, 72
lime treatment and, 72
see Water analysis
- Carbonation; 752 seq., 757
carbonate deposits and, 725
- Defiance, O., 723
- Cast-iron; chlorine, resistance to, 521
see Pipe, cast-iron
- Castor oil; boiler foaming and, 171 seq.
- Cedar Rapids, Ia.; consumption, 197
- Cement; electrical insulation and, 565
- Center Hill, Fla.; water supply, 47
- Centralia, Ill.; reservoir data, 583 seq.
- Century, Fla.; water supply, 48
- Charleston; main sterilization, 84
- Charleston, S. C.; consumption, 197
meter reading and billing, 692 seq.
tank, elevated, 291 seq.
- Charlotte, N. C.; consumption, 197
- Chatham, Ont.; fire protection charges, 653
- Chelsea, Mass.; consumption, 197
- Chesapeake & Ohio Railway; water treatment, 434
- Chester, Pa.; consumption, 197
- Chicago, Ill.; consumption, 199, 244
cross-connections, 554 seq.
treatment, experiments on, 710 seq.
typhoid, 763 seq.
- Chipley, Fla.; water supply, 47
- Chloride; limit, U. S. P. H. S., 261
- Chlorination; algae and, 444 seq.
ammonia and, 348 seq.
chlorine, liquid and, cost, 532 seq.
dechlorination, 338 seq.
double, 701 seq.
electrolytic; 514 seq.
cell efficiency, determination, 536 seq.
cost data, 529 seq.
- leptospirae and, 237
- of mains, 79 seq.
- pre-, 235, 259
- spore bearers and, 593
- suspended matter and, 79 seq., 85, 706
- taste and odor: air contamination and, 344
chlorine, free, and, 346
creosote and, 587
double chlorination and, 346
H-ion concentration and, 340
microorganisms and, 708
permanence and, 589
phenol; 336 seq., 586 seq.
tests, correlation, 343 seq.

- pipe coatings and, 81, 342, 345
- prechlorination and, 346 seq.
- prevention; ammonia and; 241 seq., 341 seq.
 - cost, 350
- ammonium chloride and, 235 seq.
- potassium permanganate and, 235 seq., 347
- superchlorination and; 242, 336 seq., 347, 589, 708
 - temperature and, 340
- season and, 259
- sewage and, 348
- tar paint and, 587
- temperature and, 344 seq.
- Chlorine; electrochemical equivalent, 528
- iron, cast, and, 521
- lead and, 521
- see* Chlorination; Water Analysis
- Chlorine Institute; chlorination, suspended matter and, 85
- Cicero, Ill.; consumption, 197
- Cincinnati, O.; consumption, 197
 - typhoid, 764 seq.
- water works funds, diversion, 304
- Citizens Water Co.; consumption, 77
 - financing, 77 seq.
 - franchise, 75 seq.
 - metering, 77
- Clearwater, Fla.; water supply, 44, 47
- Clermont, Fla.; water supply, 47
- Cleveland, O.; consumption; 197, 244
 - metering and, 463
 - filtration plant; 420 seq.
 - cost, 428
 - hydraulic jump, 1 seq., 422 seq.
 - reservoir; 417 seq., 427 seq.
 - cost, 428
 - typhoid, 764 seq.
- Clewiston, Fla.; water supply, 45 seq.
- Coagulation; alum; acid and, boiler feed and, 191
 - agitation and; 717 seq.
 - centrifugal pump and, 24 seq.
 - hydraulic jump and, 18, 22 seq.
 - lime and, 253, 539
 - in reservoirs, 705 seq., 708 seq.
 - softening and, 754 seq., 758
 - temperature and, 713
- alum and iron, 254
- iron sulfate and lime; 721 seq.
 - agitation and, 722
 - hardness and, 722
- lime and, 253 seq., 722 seq.
- magnesium and, 253 seq., 723 seq., 758
- sodium aluminate; softening and, 754 seq.
- Coagulation basin; Cleveland, O., 424
- Denver, Colo., 542
- Okeechobee City, Fla., 233
- Selma, Ala., 71
- see* Settling basin
- Coal tar; chlorination taste and, 81, 342, 345, 587
- Cocoa, Fla.; water supply, 40, 46
- Color; coagulation and, softening and, 758
 - Peridinium and, 250
 - sulfur dioxide and, 44
 - water hyacinth and, 230
- Colorado State Bd. of Health; resolution re, 609
- Columbia, Tenn.; water supply, 747
- Columbus, O.; consumption, 197
 - softening; 754 seq.
 - cost, 756
 - typhoid, 764 seq.
- Committee reports; boiler foaming and priming, 160 seq.
- contract, standard form, 110 seq.
- embrittlement of steel, 174 seq.
- municipal water supplies in relation to boiler use, 190 seq.
- water analysis, standard methods, 112 seq.
- water softening by chemicals, 151 seq.
- Complaints; handling, 90 seq., 92 seq., 98 seq.
- Condenser; corrosion; oil waste and; sewage and, 192
 - scale, steel mill waste and, 191
- Conductivity; boiler embrittlement and, 179 seq.
- Consumption; Buffalo, N. Y., 282, 285
 - Burlington, Ia., 77
 - Butte, Mont., 384
 - capita, computing, 312 seq.
 - commercial, 210 seq.
 - future, estimating, 193 seq., 206
 - Hagerstown, Md., 309
 - industrial; 210 seq.
 - rates and, 203
 - irrigation and, 211 seq.
 - Los Angeles, Cal., 209 seq., 412
 - Lufkin, Tex., 449 seq.
 - McKeesport, Pa., 364
 - metering and, 205 seq., 462 seq.
 - Milton, Mass., 311
 - New York, 244
 - St. Louis, Mo., 457, 461 seq.
 - statistics, 197 seq., 244
 - in terms of depth and area, 193 seq.
 - see* Meter reading

- Contract; standard form, committee report, 110 seq.
- Copper sulfate treatment; application, 444
 - residual copper, 445 seq.
 - spore bearers and, 593
- Coral Gables, Fla.; water supply, 42, 46
- Cormorants; pollution and; scaring, 250
- Corn waste; nitrogen content and oxygen demand, 61
- Corporation cock; connecting, 472
 - repairing, 470 seq.
- Corrosion; galvanic action, 558 seq.
 - see* Boiler corrosion; Condenser; Electrolysis; Pipe
- Corrosiveness; oxygen and, 557 seq.
- Cotton waste; nitrogen content and oxygen demand, 61
- Covington, Ky.; consumption, 197
- Covington, Tenn.; water supply, 749
- Creamery waste; nitrogen content and oxygen demand, 61
- Creatinine; excretion of, 392
- Creosote; chlorination taste and, 587
- Crescent City, Fla.; water supply, 48
- Cross-connections; piping systems, identifying, 555
 - policies, 553 seq.
 - typhoid, 332
- Crystal River, Fla.; water supply, 47
- Cyclops; depth and, 726
- Dade City, Fla.; water supply, 47
- Dallas, Tex.; consumption, 197
 - typhoid, 765 seq.
- Dania, Fla.; water supply, 41, 46
- Davenport, Fla.; water supply, 47
- Davenport, Ia.; consumption, 197
- Daytona, Fla.; water supply, 40, 47
- Daytona, O.; consumption, 197
 - flood protection, 729 seq.
 - typhoid, 764 seq.
- Daytona Beach, Fla.; water supply, 40
- Dechlorination; *see* Chlorination
- Defiance, O.; carbonation, 723
- DeFuniak Springs, Fla.; water supply, 47
- DeLand, Fla.; water supply, 47
- DeLavaud pipe; breakage, 225
 - cost, 221
 - cracking, 220 seq.
 - cutting, 221
 - interior surface, size and, 222
 - jointing, 220
 - legal aspects, 225 seq.
 - pressure, 226
 - tapping, 221 seq.
- Delaware River; interstate compact, 244
- Delray, Fla.; water supply, 46
- Denver, Colo.; consumption, 199
 - filter plant; 538 seq.
 - cost, 544 seq.
 - operating costs, 545
 - pipe line, hydraulics, 104 seq.
 - typhoid, 766 seq.
- De-oxygenation; rate; pollution and; temperature and, 124
- Depreciation; calculation, 512 seq.
- Des Moines, Ia.; consumption, 197
 - typhoid, 765 seq.
- Detroit, Mich.; billing; 697 seq.
 - complaints and, 98 seq.
 - consumption; 197, 244
 - metering and, 463
 - cyclops, 726
 - financing, 300
 - free service, 300
 - meter reading, 697 seq.
 - typhoid, 764 seq.
- Diatom; chlorination and, 451
- Digestive Ferments Co.; brilliant green bile study, 113
- Distillery waste; strength, 61
- Distribution system; night flow, satisfactory, 456
 - pitometer survey; 306 seq., 456 seq.
 - design and, 457 seq.
 - records, checking, 306
 - valve system, checking, 306 seq.
 - storage, elevated and, 291 seq.
 - see* Main; Pipe
- Divide Creek; dam, 376 seq.
- Dorr clarifier; history, 215
 - mechanism, 216
 - sludge removal with, 215 seq.
- Duluth, Minn.; consumption, 197
 - typhoid, 765 seq.
- Dunedin, Fla.; water supply, 44, 46
- Dunnellon, Fla.; water supply, 47
- Dyersburg, Tenn.; water supply, 748
- Eagle Lake, Fla.; water supply, 47
- Earth; *see* Soil
- East Bay Water Co.; consumption, 197, 200
 - electrolysis, prevention, 563 seq.
 - metering, 200
- East Chicago, Ind.; consumption, 197
- Edmonton, Alta.; fire protection charges, 653
- Electric generator; d.c. generation, efficiency, load and, 524 seq.
- Electric motor; depreciation, 361
- Electrolysis; 557 seq., 561 seq.
 - co-operative treatment, 567 seq.

- current; discharge, measuring, 566 seq.
- leakage, safe, 562
- prevention; 562 seq.
- electrical drainage, 563 seq.
- insulating joints; 564 seq.
- Elfers, Fla.; water supply, 46
- Ellenton, Fla.; water supply, 43
- El Paso, Tex.; consumption, 197
- typhoid, 765 seq.
- Elwood, Ind.; well, water level drop, 329
- Engineering Library, N. Y.; embrittlement bibliography, 188
- England; typhoid, 770
- Englewood Dam; data, 735 seq.
- Espiritu Santo Spring; water quality, 44
- Eureka, Cal.; consumption; metering, 200
- Eustis, Fla.; water supply, 47
- Evansville, Ind.; consumption, 197
- Everett, Mass.; consumption, 197
- Everglades, Fla.; water supply, 48
- Excreta; composition; oxygen demand, 392
- see Pollution; Sewage
- Extension financing; Milwaukee, Wis., 696 seq.
- rule, a general, 673 seq.
- Fairhaven Water Co.; leakage, 315
- Fall River, Mass.; consumption, 197
- typhoid, 761 seq.
- Falmouth, Fla.; well, 40
- Farmington, Me.; funds, diversion, 297
- Fernandina, Fla.; water supply, 48
- Filter; laboratory, 714 seq.
- Filtration; fire protection charges and, 650, 659
- leptospires and, 237 seq.
- softening and, 53
- Filtration, double; alum required, 546 seq.
- bacterial efficiency, 549 seq.
- economy of, 546 seq.
- filter runs, 549 seq.
- rate, 239, 545 seq., 549
- Filtration, rapid sand; air binding, pumps and, 477
- alum required, 718 seq.
- bacterial removal, turbidity and, 714
- Buffalo, N. Y., 289 seq.
- Cleveland, O., 420 seq.
- cost; initial, 290, 428, 544 seq.
- operating, 545
- Denver, Colo., 538 seq.
- effluent inspection wells, 542
- filter runs, limit, 711 seq.
- media, anthracite coal, 542
- microorganisms; lime treatment and, 725
- passing of, 538
- Okeechobee City, Fla., 233
- oxygen changes, 476 seq.
- Selma, Ala., 71 seq.
- underdrains; 542
- hydraulics, 667 seq.
- washing, effluent turbidity and, 712
- Filtration, slow sand; efficiency, rate and, 550
- see Filtration, double
- Financing; bond; law, a model, 602 seq.
- sinking fund, 603
- Burlington, Ia., 77 seq.
- Funds, diversion; 296 seq.
- law and, 297, 304 seq.
- Louisville, Ky., 300 seq.
- municipal use, charging for, 77, 298, 300
- return, fair rate, 510
- service at cost or at profit, 298 seq.
- see Accounting; Extension; Fire protection; Rates; Valuation
- Fire hydrant; cost and fixed charges, 653, 665
- inspection, frequency, 659
- see Fire protection
- Fire insurance rates; storage, elevated, and, 367
- Fire loss; America, 1925, 67
- Fire protection; charging for; 77, 96 seq., 304, 647 seq.
- filtration and, 650, 659
- formula, 651
- hydrant rental and, 97, 647 seq., 651 seq.
- law and, 663
- main, inch-feet and, 651 seq., 656
- main mileage and, 97, 651 seq.
- statistics, Canada, 653
- pressure system, 287 seq.
- pumping requirements and, 648 seq., 661
- water works investment and, 647 seq., 661
- Fire protection, private; see Sprinkler system
- Fire underwriters; see National Board; Pacific Board
- Flint, Mich.; consumption, 197
- typhoid, 764 seq.
- Flood control; Miami Valley, 727 seq.
- Florida; rainfall, 37
- water supplies, 37 seq.
- Florida Power & Light Co.; water supply, 42

- Florida Section; organization meeting, 396 seq.
- Florida State Bd. of Health; water examination, regulations, 50
- Flow; through contractions, 12
critical depth, 1, 12
maximum, theory, 12
- Forestation; N. Carolina Section report, 491
- Fort Lauderdale, Fla.; water supply, 41, 46
- Fort Meade, Fla.; water supply, 47
- Fort Myers, Fla.; water supply, 43, 48
- Fort Pierce, Fla.; water supply, 40, 48
- Fort Wayne, Ind.; water shortage, 330
- Fort Worth, Tex.; consumption, 197
typhoid, 765 seq.
- Four Mile Creek, flood control, 727 seq.
- Franklin, O.; flood protection, 734
- Fresno, Cal.; consumption; metering, 200
- Frostproof, Fla.; water supply, 48
- Fruitland Park, Fla.; water supply, 47
- Gainesville, Fla.; water supply, 45 seq., 47
- Gantt, Ala.; malaria and impounded water, 481 seq.
- Gary, Ind.; consumption, 197
- Gas works' waste; chlorination taste and, 337 seq.
- Geophone; leakage detection and, 310
- Germantown Dam; data, 735 seq.
- Germany; typhoid, 770
- Glendale, Cal.; consumption; metering, 200
- Glue waste; nitrogen content and oxygen demand, 61
- Goiter; iodine and, 239 seq.
turbidity and, 240
- Graceville, Fla.; water supply, 48
- Grand Rapids, Mich.; consumption, 197
typhoid, 764 seq.
- Green Cove Springs, Fla.; Quissana Springs, 39
water supply, 47
- Greensand; *see* Softening
- Greensburg, Ind.; well, water level drop, 329
- Greenville, Fla.; water supply, 47
- Greenville, Tenn.; chlorination taste, ammonia and, 341 seq.
water supply, 747
- Greenwich Water Co.; deLavaud pipe, 224, 226
- Groveland, Fla.; water supply, 47
- Hagerstown, Md.; consumption, 309
leakage reduction, 309 seq.
- Haines City, Fla.; water supply, 46
- Hamilton, O.; flood protection, 734
- Hamilton, Ont.; fire protection charges, 653
- Hampton Springs, Fla.; water supply, 39
- Hardness; algae and, 251
H-ion concentration and, 573 seq.
lime-iron coagulation and, 722
see Softening: Water Analysis
- Harrisburg, Pa.; consumption, 197
filtration, double, 546 seq.
- Hartford, Conn.; consumption, 197
rates, system, 92
typhoid, 761 seq.
- Hastings, Fla.; water supply, 40, 48
- Havana, Fla.; water supply, 47
- Hazleton, Ind.; water supply, 331
- High Springs, Fla.; water supply, 48
- Highland Park, Mich.; filtration, oxygen, changes and, 476 seq.
- Highway; comfort station, specifications, 439 seq.
sanitation, 435 seq.
water supply survey, 440 seq.
- Hippuric acid; excretion of, 392
- Hoboken, N. J.; consumption, 197
- Hollywood, Fla.; water supply, 41, 46
- Homestead, Fla.; water treatment, 42, 46
- Hot Springs, Ark.; water quality, 261
- Houston, Tex.; consumption, 197
typhoid, 765 seq.
- Huffman Dam; data, 735 seq.
- Huntingburg, Ind.; water shortage, 329 seq.
- Hydrant; *see* Fire hydrant
- Hydraulic jump; aeration and, 26
definition, 1
as mixing device, 1 seq., 422 seq.
- Hydrogen electrode; *see* Water analysis
- Hydrogen ion concentration; alkalinity and, 573 seq.
boiler water control, 570 seq.
chlorophenol taste and, 340
hardness and, 573 seq.
softening, lime, and, 759
see Buffer value: Water Analysis
- Hydrogen sulfide; stratification and, 248
- Illinois River; oxygen absorption, 62
- Illinois Section; meeting, 610 seq.
- Illness; *see* Jaundice; Typhoid
- Indiana; water shortage, 327 seq.
wells, level drop, 329

- Indiana Public Service Commission;
 Indianapolis Water Co. case, 505
 seq.
 Indiana Section; meeting, 787 seq.
 Indianapolis, Ind.; typhoid, 764 seq.
 Indianapolis Water Co.; consump-
 tion, 199
 rate case, 505 seq.
 Industrial wastes; nitrogen content
 and oxygen demand of, 61
 see Pollution, industrial wastes
 Intake; Buffalo, N. Y., 281, 283
 Denver, Colo., 539
 Racine, Wis., 106 seq.
 International Joint Commission on
 Pollution of Boundary Waters;
 purification plant loading, 59 seq.
 Inverness, Fla.; water supply, 47
 Iodine; goiter and, 239 seq.
 Iowa Section; meeting, 129 seq.
 Iron; *see* Cast iron; Pipe, iron
 Iron removal; Selma, Ala., 69 seq.
 softening, 758
 Irrigation; Water required, 211 seq.
 see Lindsay Strathmore Irrigation
 District

 Jackson, Mich.; consumption, 197
 Jackson, Miss.; filtration; coagula-
 tion, 718 seq.
 Jacksonville, Fla.; consumption, 197
 rainfall, 37
 typhoid, 763 seq.
 water supply, 39, 48
 Jacksonville Beach, Fla.; water sup-
 ply, 48
 Jasper, Fla.; water supply, 47
 Jaundice; water-borne, 236 seq.
 Jennings, Fla.; water supply, 47
 Jersey City, N. J.; typhoid, 762 seq.
 Johnson City, Tenn.; water supply,
 747
 Jupiter, Fla.; rainfall, 37

 Kalamazoo, Mich.; consumption, 197
 Kalamein pipe; *see* Pipe, steel
 Kansas City; Dorr clarifier, 215 seq.
 Kansas City, Kans.; consumption,
 197
 typhoid, 765 seq.
 Kansas City, Mo.; consumption, 197
 typhoid, 765 seq.
 Kaweah River; litigation re, 322 seq.
 run-off, 321
 Kentland, Ind.; well, level drop, 329
 Kentucky-Tennessee Section; meet-
 ing, 604 seq.
 stream pollution resolution, 608
 Key West Water District; water
 supply, 42 seq.

 Kharkow Water Supply Bd.; filter
 underdrains, hydraulics, 671
 Kingsport, Tenn.; water supply, 747
 Kissimmee, Fla.; water supply, 48
 Kitchener, Ont.; fire protection
 charges, 653
 Knoxville, Tenn.; water supply, 747
 Kokomo, Ind.; well, level drop, 329

 Lake Alfred, Fla.; water supply, 47
 Lake City, Fla.; water supply, 38, 47
 Lake Helen, Fla.; water supply, 47
 Lake Wales, Fla.; water supply, 47
 Lake Worth, Fla.; water supply, 46
 Lakeland Fla.; water supply, 47
 Lakewood, Ohio; consumption, 198
 Lansing, Mich.; consumption, 198
 Largo, Fla.; water supply, 47
 Lawrence, Mass.; consumption, 198
 Lead; chlorine, corrosion and, 521
 Leadite; *see* Pipe
 Leakage; detection; geophone and,
 310
 sound intensifiers and, 309
 reduction, pitometer survey and,
 306 seq.
 see Water, unaccounted for
 Leesburg, Fla.; water supply, 47
 Leptospirae; chlorination and, 237
 filtration and, 237 seq.
 isolation and identification, 238
 jaundice and, 236 seq.
 Lexington Water Co.; leakage re-
 duction, 309
 water, unaccounted for, 309
 Liebreich zone; 165 seq.
 Lime treatment; boiler feed and, 191
 carbon dioxide and, 72
 carbonate deposits, recarbonation
 and, 725
 microorganisms and, 259, 446 seq.,
 725
 mixing, hydraulic jump and, 18
 seq.
 sterilization and, 259, 759
 see Coagulation: Softening
 Lincoln, Neb.; consumption, 198
 Lindsay Strathmore Irrigation Dis-
 trict; litigation, 322 seq.
 organization, 318 seq.
 rates, 325
 water cost, 325
 Linton, Ind.; well, level drop, 329
 Live Oak, Fla.; water supply, 38, 48
 Lock Joint Pipe Co.; hydraulic
 studies, 103 seq.
 Lockington Dam; data, 735 seq.
 London, Eng.; chlorination, taste
 prevention, 235 seq.
 filtration, double, 241

- leptospirae investigation, 236 seq.
- typhoid, 770
- water supply, report, 235 seq.
- London (Eng.) Metropolitan Water Bd.; annual report, 235 seq.
- London, Ont.; fire protection charges, 653, 663 seq.
- Long Beach, Cal.; consumption, 200, 213
- metering, 200
- Longwood, Fla.; water supply, 47
- Loramie Creek; flood control, 727 seq.
- Los Angeles, Cal.; aqueduct, Colorado River, 409 seq.
- aqueduct, Los Angeles, cost, 415
- consumption; 198, 200, 209 seq., 244, 412
- metering and, 463
- metering, 200
- rates, 413
- reservoirs, biological control, 247 seq.
- water supply situation, 410 seq.
- typhoid, 766 seq.
- Louisville, Ky.; financing, 300 seq.
- typhoid, 765 seq.
- Loveland, Colo.; phenol tastes, 586 seq.
- Lowell, Mass.; consumption, 198
- typhoid, 760 seq.
- Lufkin, Tex.; algae control, 449 seq.
- consumption, 449
- Lynn, Mass.; typhoid, 761 seq.
- McKees Rocks, Pa.; *see* Ohio Valley Water Co.
- McKeesport, Pa.; consumption, 364
- pumps, operating costs, 356 seq.
- Mad River; flood control, 727 seq.
- Madison, Fla.; water supply, 47
- Madison, Wis.; consumption, 198
- Magnesium; limit, U. S. P. H. S., 261
- removal, lime treatment, 723 seq.
- Magnesium chloride; boiler corrosion and, 180
- buffering and, 573
- conductivity and, 180
- solubility, 180
- Magnesium hydroxide; coagulation with, 253 seq., 723 seq., 758
- Magnesium sulfate; conductivity and, 180
- hydrolysis, 571 seq.
- solubility, 180
- Main; cleaning, 287, 459 seq.
- cracked, repairing, 471 seq.
- disinfection of, 79 seq.
- dual on wide streets; 740 seq.
- cost, 744 seq.
- plugs, replacing, 471
- subway construction, protection and, 629 seq.
- see* Distribution System; Electrolysis; Extension; Pipe
- Maine Public Utility Commission; water works funds, diversion and, 297
- Malaria; *see* Anopholes; Reservoir
- Malden, Mass.; consumption, 198
- Manatee, Fla.; water supply, 43, 48
- Manchester, N. H.; consumption, 198
- Marengo, Ind.; water supply, 331
- Marianna, Fla.; water supply, 47
- Marion, Ind.; well, level drop, 329
- Marked Tree, Ark.; water quality, 262
- Marysville, Cal.; consumption; metering, 200
- Massachusetts Metropolitan Water District; consumption, 198
- Matheson Joint Pipe; *see* Pipe, steel
- Mayo, Fla.; water supply, 47
- Medford, Mass.; consumption, 198
- Melbourne, Fla.; water supply, 46
- Memphis, Tenn.; consumption, 198
- typhoid, 764 seq.
- water supply, 747 seq.
- Mena, Ark.; water quality, 261 seq.
- Meter; accuracy, pressure and, 317
- batteries of, 464
- compound, 464
- hot water damage; charging for 464
- check valves and, 464
- maintenance methods, 464 seq.
- over-registration; complaints and, 92 seq.
- disc type and, 317
- turbine type and, 316 seq.
- testing; frequency, 464
- pitometer and, 460
- regulations, 93 seq.
- Meter reading; consumption, unusual, notices re, 684 seq., 694, 695, 698
- continuous vs. periodic, 683 seq.
- errors, eliminating, 693
- frequent, economy of, 686
- practice, 687 seq.
- Metering; Buffalo, N. Y., 285, 314
- Burlington, Ia., 77
- Butte, Mont., 384
- consumption and, 205 seq., 462 seq.
- Milton, Mass., 311
- St. Louis, Mo., 461
- sprinkler services and, 66
- statistics, California, 200
- Mexia, Tex.; algae control, 446 seq.
- Miami, Fla.; water treatment, 41 seq., 46

- Miami Beach, Fla.; water supply, 42, 46
 Miami Conservancy District; flood protection project; 727 seq.
 cost, 737
 organization, 731 seq.
 Miami River; flood control, 727 seq.
 Miami Water Co.; water supply, 42
 Miamisburg, O.; flood protection, 734
 Michigan, Lake; treatment, experiments, 710 seq.
 Microscopic examination; committee report, 118 seq.
 Microscopic organisms; filtration, rapid sand and, 538
 lime treatment and, 725
 reservoir, level and, 701
 taste and odors, super-chlorination and, 708
 see Algae
 Middletown, O.; flood protection and, 734
 Milton, Fla.; water supply, 47
 Milton, Mass.; consumption, 311
 leakage, detection, 310
 metering, 311
 pipe; cement-lined, 223
 deLavaud, 222 seq.
 water unaccounted for, 311
 Milwaukee, Wis.; consumption; 198
 metering and, 463
 extension financing, 696 seq.
 meter reading and billing, 683 seq.
 phenol waste, sewage and, 348
 rates, 693
 typhoid, 764 seq.
 Minneapolis, Minn.; consumption, 198
 typhoid, 765 seq.
 Missouri; highway sanitation, 435 seq.
 Missouri River; self purification, 62
 Mitchell Dam; malaria and, 36
 Mixing; *see* Agitating device; Agitation
 Mixing basin; alum dosage and, 718 seq.
 Selma, Ala., 70
 Modesto, Cal.; consumption; metering, 200
 Montana Section; meeting, 489 seq.
 Monticello, Fla.; water supply, 47
 Montreal, Que.; filtration, double; 550 seq.
 costs, 545, 551
 fire protection charges, 653
 Moore Haven, Fla.; water supply, 45 seq.
 Mosquito; *see* Anopholes
 Moulton Dam; 377 seq.
 Mount Dora, Fla.; water supply, 45 seq.
 Mudhen; pollution and, 250
 Mulberry, Fla.; water supply, 47
 Muncie, Ind.; well, level drop, 329
 water supply, 329
 Munich, Ger.; typhoid, 770
 Nashville, Tenn.; typhoid, 764 seq.
 water supply, 747
 National Bd. of Fire Underwriters; fire loss, 1925, 67
 sprinkler services, metering of, 66
 National Municipal League; model bond law, 602 seq.
 New Bedford, Mass.; consumption, 198
 deLavaud pipe, 223
 typhoid, 760 seq.
 New Britain, Conn.; consumption, 198
 New Brunswick; meters, 317
 New Haven, Conn.; typhoid, 761 seq.
 New Jersey; Delaware River compact, 244
 New Orleans, La.; consumption, 198
 typhoid, 765 seq.
 New Port Richey, Fla.; water supply, 47
 New Smyrna, Fla.; water supply, 40, 47
 New Toronto, Ont.; fire protection charges, 653
 New Valparaisa, Fla.; water supply, 38
 New York City; chlorination, double, 701 seq.
 coagulation, 705 seq., 708 seq.
 consumption, 199, 244
 reservoir, low level; 699 seq.
 flood, 1926, and, 704 seq.
 typhoid, 761 seq.
 water supply; extension, 243 seq.
 subway construction and, 629 seq.
 New York State; Delaware River compact, 244
 Newark, N. J.; consumption, 198
 typhoid, 762 seq.
 Newberry, Fla.; water supply, 47
 Niagara Falls, Ont.; fire protection charges, 653
 meter reading and billing, 698
 Nitrogen as albuminoid ammonia; significance, 389 seq., 393 seq.
 see Water analysis
 Nitrogen as free ammonia; significance, 388, 393 seq.
 see Water analysis

- Norfolk, Va.; lock joint pipe, 105
typhoid, 763 seq.
- North Carolina Section; meeting, 490
seq.
stream gaging and forestation
report, 491
- Oak Park, Ill.; consumption, 198
- Oakland, Cal.; rates, 413
typhoid, 766 seq.
- Obituary; Merritt H. Smith, 127 seq.
- Ocala, Fla.; water supply, 45, 48
- Ocoee, Fla.; water supply, 47
- Odor; algae and, 444
stratification and, 248
see Chlorination
- Ohio; Conservancy Act, 729 seq.
- Ohio River; flow, time of, 62
- Ohio Valley Water Co.; meter; over-
registration complaints, 92 seq.
testing regulations, 93 seq.
softening, cost, 756
- Oil waste; boiler foaming and cor-
rosion and, 192
condenser corrosion and, 192
- Okeechobee City, Fla.; water supply
investigation, 227 seq.
water works, 45 seq., 227 seq.
- Okeechobee Lake; water supply in-
vestigation, 227 seq.
- Oklahoma City, Okla.; coagulation,
calcium and magnesium hydroxides
and, 253 seq.
water treatment, 253 seq.
- Olympia, Wash.; financing, ruling
re, 304 seq.
- Omaha, Neb.; consumption, 198
typhoid, 765 seq.
- Orange City, Fla.; water supply, 47
- Organic matter; boiler foaming and,
168, 172
- Orillia, Ont.; fire protection charges,
653
- Orlando, Fla.; water treatment, 45
seq.
- Ormond, Fla.; water supply, 40, 47
- Ortho-tolidin; *see* Water analysis
- Oscillaria; chlorination and, 446
seq., 451 seq.
lime treatment, 446 seq.
- Oswego, N. Y.; leakage, detection,
311
- Ottawa, Ont.; fire protection charges,
653
- Oxygen demand; birds and, 250
of industrial wastes, 61
see Water analysis
- Oxygen dissolved; air, absorption
from, 62
birds and, 250
boiler embrittlement and, 182
corrosiveness and, 557 seq.
filtration, rapid sand, and, 476 seq.
Scenedesmus and, 249
stratification and, 248
supersaturation, 120
see De-oxygenation; Water analysis
- Pacific Bd. of Fire Underwriters;
sprinkler connections, charges for,
64 seq.
- Palatka, Fla.; water supply, 46 seq.
- Palmetto, Fla.; water supply, 43, 48
- Palo Alto, Cal.; consumption; meter-
ing, 200
- Panacea, Fla.; well, 39
- Panama City, Fla.; water supply, 47
- Paper waste; nitrogen content and
oxygen demand, 61
- Paris, Tenn.; water supply, 748
- Pasadena, Cal.; consumption; meter-
ing, 200
- Passagrille, Fla.; water supply, 44, 47
- Paterson, N. J.; consumption, 198
typhoid, 762 seq.
- Pavement; patching, 472 seq.
- Pawtucket, R. I.; consumption, 198
- Pensacola, Fla.; rainfall, 37
water supply, 37 seq., 47
- Pennsylvania; Delaware River com-
pact, 244
- Pennsylvania Water Co.; leadite,
experience with, 94 seq.
- Peridinium; birds and; color and;
taste and odor and, 250
- Permutit Co.; boiler embrittlement,
183 seq.
- Perry, Fla.; water supply, 46
- Peterborough, Ont.; fire protection
charges, 647 seq.
- Petersburg, Ind.; water supply, 331
- Phenol; sewage and, 348
see Chlorination; Water analysis
- Philadelphia, Pa.; consumption, 199,
244
typhoid, 761 seq.
- Pierce, Fla.; water supply, 47
- Pine-tar oil; boiler foaming and, 172
- Pipe; coatings; chlorination taste
and, 81
tar, value, 87
corrosion, parallel pipes and, 560
joint, leadite; leakage and, 94 seq.
practice, 94 seq.
laying, cost accounting and, 368
seq.
- Scotch, durability, 645 seq.
- soil corrosion; cathodic protection
and, 561
covering and, 383, 561

- soil resistance and, 561
- see* Distribution system; Electrolysis; Main; Services
- Pipe, cast iron; coatings, 87
- failure; 639
- stress and, 635
- repairing, 639
- specifications, 600 seq.
- Universal, joints, repairing, 473
- see* DeLavaud pipe; Pipe, cement-lined
- Pipe, cement-lined; carrying capacity, 88 seq.
- fittings, 222 seq.
- life and, 87 seq.
- lining; cost, method, thickness, 88
- tuberculation, 87 seq.
- Pipe, concrete; flow in, 105
- Lock Joint, carrying capacity, 103 seq.
- Pipe, iron; *see* Pipe, cast iron; Pipe, wrought iron
- Pipe, steel; committee on, 595 seq.
- corrosion, mill scale and, 559
- joints, welded, 382
- Kalamein, flexible, 382 seq.
- Matheson joint, life, 386
- stress, resistance to, 635
- Pipe, wood; life, 386
- Pipe, wrought iron; repairing, 474
- see* Pipe, cement-lined
- Piqua, O.; flood protection, 734
- Pitometer; meter testing and, 460
- see* Distribution system; Leakage; Waste
- Pittsburgh, Pa.; typhoid, 761 seq.
- Plant City, Fla.; water supply, 47
- Pollution; birds and, 250
- condenser corrosion and, 192
- de-oxygenation rate; temperature and, 124
- indicators of; nitrogen forms; urea, 394
- Pollution, industrial wastes; oil, boiler feed and, 192
- oxygen demand of various, 61
- steel mill, boiler feed and, 191
- Pollution, stream; effects of, 58 seq.
- Portland, Ore.; typhoid, 766 seq.
- Potassium hydroxide; conductivity; solubility, 180
- Potassium permanganate; chlorination taste and, 235 seq., 347
- Prechlorination; *see* Chlorination
- Pressure; storage, elevated and, 291 seq.
- Pressure gage; recording, value, 352
- Protococcus; chlorination and, 446 seq., 454
- lime treatment and, 446 seq.
- Providence, R. I.; consumption, 198
- typhoid, 761 seq.
- Public relations; *see* Complaints
- Pump; centrifugal, operating cost, 356 seq.
- filter air binding and, 477
- slippage, checking, 312
- see* Well
- Pumping station; auxiliaries, selection, 355
- Buffalo, N. Y., 284, 286 seq.
- Butte, Mont., 378 seq.
- coal consumption, piping layout and, 286
- drive, electric, peak loads and, 365 seq.
- fire protection and, 648 seq., 661
- log, essential data, 351 seq.
- Okeechobee City, Fla., 232 seq.
- Punta Gorda, Fla.; water supply, 43, 47
- Purification; loading, limit, 59 seq.
- self-, 62
- Purity Springs Water Co.; 44
- Quebec, Que.; fire protection charges, 653
- Quincy, Fla.; water supply, 47
- Quincy, Ill.; lime treatment, 725
- Quincy, Mass.; consumption, 198
- Quinhydrone electrode; *see* Water analysis
- Qui-si-sana Springs; water, 39
- Racine, Wis.; consumption, 198
- water works rehabilitation, 106 seq.
- Railroad supplies; sodium sulfate, foaming and corrosion and, 430
- treatment; barium salts and, 56
- checking, analytical methods, 433
- corrosiveness, reducing, 56
- cost, 429, 434
- economy of, 433 seq.
- filtration, 53 seq., 432 seq.
- future and, 51 seq.
- internal, 56
- lime-soda, 432 seq.
- oxygen removal, 56
- soda ash, foaming and, 431
- supervision and, 433 seq.
- suspended matter removal, 52 seq.
- tanks, sludge removal, 54 seq.
- zeolite, 55, 431 seq.
- see* Boiler; Softening
- Rainfall; Florida, 37
- predicting, 335
- Richmond, Ind., 333 seq.
- Rates; Buffalo, N. Y.; 288
- complaints and, 90 seq.

- Indianapolis Water Co. case, 505 seq.
 industrial consumption and, 203
 Lindsay Strathmore Irrigation District, 325
 Los Angeles, Cal., 413
 Milwaukee, Wis., 693
 Oakland, Cal., 413
 San Francisco, Cal., 413
 systems; consumers and, 89 seq.
 ready to serve, 89 seq.
 valuation, 505 seq.
 Reading, Pa.; typhoid, 762 seq.
 Redlands, Cal.; consumption; metering, 200
 Redwood, Cal.; consumption; metering, 200
 Regina, Sask.; fire protection charges, 653
 Remington, Ind.; well, level drop, 329
 Reservoir; algae, birds and, 250
 birds, discouraging, 250 seq., 466 seq.
 Cleveland, O.; 417 seq., 427 seq.
 cost, 428
 coagulation in, 705 seq., 708 seq.
 impounding; biological control, 247 seq.
 low level; 699 seq.
 floods and, 704 seq.
 malaria and, 481 seq.
 water available, 583 seq.
 microorganisms, level and, 701
 pollution; birds and, 250
 level and, 701
 mosquito control; 31 seq.
 algae and, 35
 floatage and, 33 seq.
 Gambusia and, 34
 Spirogyra and, 35
 wave action and, 34
 stagnation; 248
 algae and, 248
 stratification, 247 seq.
 see Tank
 Richmond, Ind.; rainfall, 333 seq.
 water shortage, 330
 water supply, 333 seq.
 Richmond, Va.; consumption, 198
 typhoid, 763 seq.
 Ripley, Tenn.; water supply, 748
 River Junction, Fla.; water supply, 47
 Riverside, Cal.; consumption; metering, 200
 Rochester, Ind.; water supply, 332
 Rochester, N. Y.; consumption; 198
 metering and, 463
 typhoid, 762 seq.
- Rocky Mountain Section; Colorado Engineering Council and, 609
 Colorado State Bd. of Health, resolution re, 609
 meeting, 608 seq.
- Sacramento, Cal.; chlorination, electrolytic, 514 seq.
 consumption; metering, 200
 Safety Harbor, Fla.; water supply, 44, 47
 Saint Augustine, Fla.; water quality, 39, 46
 Saint Catharines, Ont.; fire protection charges, 653
 Saint Cloud, Fla.; water supply, 47
 Saint Louis, Mo.; consumption, 199, 244, 457, 461 seq.
 cyclops, 726
 Dorr clarifier, 215 seq.
 metering, 461
 pipe cleaning, 459 seq.
 pitometer survey, 456 seq.
 typhoid, 765 seq.
 waste reduction, 461 seq.
 Saint Paul, Minn.; consumption, 198
 typhoid, 765 seq.
 Saint Petersburg, Fla.; main sterilization, 83
 pipe, deLavaud, 223
 water supply, 44, 48
 Saint Thomas, Ont.; fire protection charges, 653, 660 seq.
 Salt Lake City, Utah; typhoid, 766 seq.
 San Antonio, Tex.; typhoid, 765 seq.
 San Bernardino, Cal.; consumption; metering, 200
 San Diego, Cal.; consumption; metering, 200
 typhoid, 766 seq.
 San Francisco, Cal.; consumption, 198, 200, 213
 metering, 200
 rates, 413
 seagull problem, solving, 466 seq.
 typhoid, 766 seq.
 water supply situation, 416
 San Jose, Cal.; consumption; metering, 200
 San Mateo, Cal.; consumption; metering, 200
 Sanford, Fla.; water supply, 48
 Sanitary survey; highway supplies, 440 seq.
 Santa Ana, Cal.; consumption; metering, 200
 Santa Barbara, Cal.; consumption; metering, 200

- Santa Cruz, Cal.; consumption; metering, 200
 Santa Rosa, Cal.; consumption; metering, 200
 Sarasota, Fla.; water supply, 43, 47
 Scale; constituents forming, calculation, 262
 Scenedesmus; oxygen dissolved and, 249
 Scranton, Pa.; consumption, 198
 typhoid, 762 seq.
 Screens; spray-cleaned, 539
 Sea Gull; pollution and, 250
 reservoir, ridding of, 466 seq.
 Seabreeze, Fla.; water supply, 40
 Seattle, Wash.; consumption, 198
 typhoid, 766 seq.
 Sebring, Fla.; water supply, 47, 50
 Sedimentation; surface layer and, 166
 see Settling basin
 Selma, Ala.; iron removal plant, 69 seq.
 Seminole Heights Water Co.; 44
 Services; corrosion at gooseneck; 558 seq.
 prevention, 559
 freezing, protection and, 643
 subway construction and, 636
 Settling basin; Selma, Ala., 70
 sludge removal; diaphragm pump, 219
 Dorr clarifier; 215 seq.
 sludge density and, 216
 water loss and, 219
 Seven Mile Creek; flood control, 727 seq.
 Sewage; composition, 60
 condenser corrosion and, 192
 nitrogen determinations, significance, 388 seq.
 oxygen demand, 60
 treatment, dilution; de-oxygenation rate, temperature and, 124
 dilution required, 62
 oxygen required, 392
 Shelbyville, Tenn.; water supply, 747
 Shreveport, La.; consumption, 198
 Silver Bow Creek; dam, 378
 Silver Springs; description; flow, 45
 Slaughter house waste; nitrogen content and oxygen demand, 61
 Soap waste; nitrogen content and oxygen demand, 61
 Society affairs; Section; California, 263 seq.
 Canadian, 788 seq.
 Florida, 396 seq.
 Illinois, 610 seq.
 Indiana, 787 seq.
 Iowa, 129 seq.
 Kentucky-Tennessee, 604 seq.
 Montana, 489 seq.
 North Carolina, 490 seq.
 Rocky Mountain, 608 seq.
 Soda ash treatment; see Railroad supplies; Softening
 Sodium aluminate; see Coagulation
 Sodium bicarbonate; see Boiler
 Sodium carbonate; conductivity; hydrolysis; solubility, 180
 see Boiler
 Sodium chloride; boiler corrosion and, 180
 conductivity; solubility, 180
 unit weight, 515
 Sodium hydroxide; boiler embrittlement and, 174 seq.
 conductivity; solubility, 180
 Sodium sulfate; conductivity; solubility, 180
 see Boiler; Railroad supplies
 Sodium sulfite; dechlorination and, 338 seq.
 Softening; algae and, 251
 filtration and, 53
 lime, excess; 722 seq.
 pH and, 759
 sterilization and, 759
 lime-zeolite, 756 seq.
 lime-soda; 751 seq.
 agitation and, 753
 coagulation and, 753 seq., 758
 cost, 756
 excess, cost, 754
 iron removal and, 758
 limits, complex salts and, 753 seq.
 zeolite, greensand; 755 seq.
 base exchange capacity, 756
 cost, 756
 salt requirement, 756
 wash water and, 756
 see Boiler feed; Carbonation; Lime treatment; Railroad supplies
 Soil; bearing value, study, 292 seq.
 corrosion by, resistance and, 561
 earth current meter, 566 seq.
 Solids, total; limit, U. S. P. H. S., 261
 Solution pressure; 558
 Somerville, Mass.; consumption, 198
 South Fork Dam; 376 seq.
 South Jacksonville, Fla.; water supply, 48
 South Pittsburgh Water Co.; rates, 89 seq.
 Spirogyra; chlorination and, 449 seq.
 mosquitoes and, 35
 Spokane, Wash.; consumption, 198
 typhoid, 766 seq.

- Springfield, Ill.; consumption, 198
Springfield, Mass.; consumption, 198
 typhoid, 761 seq.
Sprinkler system; illicit use, preventing, 66
 metering, 66
 services, charges for, 64 seq.
Stagnation; Scenedesmus and, 249
 stratification and, 248
Standpipe; *see* Tank
Starke, Fla.; water supply, 47
Steam; piping leaks, stopping, 472
 see Boiler
Steel wastes; boiler feed and, 191
Steelton, Pa.; alum dosage, 546, 550
 double filtration, 546 seq., 550 seq.
Sterilization; *see* Chlorination; Lime treatment
Stillwater River; flood control, 727 seq.
Stirrer; laboratory, 716 seq.
Stockton, Cal.; consumption; metering, 200
Storage; elevated; fire insurance rates and, 367
 pressure and, 291 seq.
Stratford, Ont.; fire protection charges, 653
Stratification; hydrogen sulfide and, 248
 odors and, 248
 oxygen and, 248
 prevention, 248
 stagnation and, 248
 temperature and, 247 seq.
 see Thermocline
Strawboard waste; nitrogen content and oxygen demand, 61
Stream; gaging, N. Carolina Section report, 491
 self purification, 62
 see Pollution, stream
Stuart, Fla.; water supply, 40, 46
Sulfate; limit, U. S. P. H. S., 261
 see Sodium sulfate
Sulfur dioxide; color, bleaching with, 44
Sulfuric acid treatment; boiler feed and, 191
Sunny Isles, Fla.; water supply, 46
Surface concentration; boiler foaming and, 164 seq.
 surface tension and, 166
Surface layer; boiler foaming and, 165 seq.
 sedimentation and, 166
Surface tension; boiler foaming and, 164 seq.
 concentration and, 166
Susquehanna River; water quality, 550
Suwannee, Fla.; well, 39
Swallow; pollution and, 250
Synura; copper sulfate treatment and, 706
Syracuse, N. Y.; consumption, 198
 leakage reduction, 310
 meters, accuracy, 316 seq.
 typhoid, 762 seq.
 waste survey, 315 seq.
Syracuse Suburban Water Co.; water unaccounted for, 309
Tacoma, Wash.; typhoid, 766 seq.
Tallahassee, Fla.; water supply, 38, 47
Tampa, Fla.; color, sulfur dioxide and, 44
 rainfall, 37
 water works, 43 seq., 46 seq.
Tank, elevated; birds, discouraging, 294
 committee on, 595
 overflow, 294
 pressure and, 291 seq.
 settlement, 293 seq.
 soil investigation and, 292 seq.
 see Storage
Tannery waste; nitrogen content and oxygen demand, 61
Tarpon Springs, Fla.; water supply, 44, 46
Taste and odor; Peridinium and, 250
 see Chlorination
Taunton, Mass.; consumption, 198
Tavares, Fla.; water supply, 47
Taxation; municipal ownership and, 298, 655, 664 seq.
Taylorsville Dam; data, 735 seq.
Temperature; stratification and, 247 seq.
Tennessee; water supplies; problems, 746 seq.
 State Bd. of Health control, 749 seq.
Terre Haute, Ind.; consumption, 198
Thermocline; depth and, 248
Thiocyanate; excretion of, 392
Titusville, Fla.; water supply, 40, 46
Toledo, O.; consumption, 198
 typhoid, 764 seq.
 water works operation, 352
o-tolidin; *see* Water analysis
Topeka, Kans.; consumption, 198
Toronto, Ont.; fire protection charges, 653, 658
Trenton, N. J.; typhoid, 762 seq.
Troy, O.; flood protection, 734

- Tulsa, Okla.; lock joint pipeline, 105
 spore-bearers, 591 seq.
 typhoid, 765 seq.
- Tungsten electrode; *see* Water analysis
- Turbidity; chlorination and, 706
 goiter and, 240
 limits, 261, 704, 714
see Water analysis
- Twin Creek; flood control, 727 seq.
- Typhoid; cross-connections and, 332
 England, 770
 Germany, 770
 United States, survey, 1926, 760 seq.
- Umatilla, Fla.; water supply, 47
- United States; fire loss, 1925, 67
 population, distribution, 58 seq.
 typhoid, 1926, 760 seq.
 water works; cost, per capita, 106 number, 59
- Urea; excretion of, 392
 nitrogen determinations and, 388 seq.
 pollution, as indicator of, 394
- Uric acid; excretion of, 392
- Utica, N. Y.; consumption, 198
 typhoid, 761 seq.
- Utilities; return, fair, 510
see Taxation; Valuation
- Vallejo, Cal.; consumption; metering, 200
- Valuation; for rate making, 505 seq.
- Verdi Gris River; water supply, flow and, 60
- Vero Beach, Fla.; water supply, 48
- Vevay, Ind.; water supply, 331
- Walkerville, Mont.; water supply, 372
- Walkerville, Ont.; fire protection charges, 653
- Waltham, Mass.; consumption, 198
- Washington, D. C.; consumption, 198
 typhoid, 763 seq.
 water supply; conduit, 28 seq.
 increasing, 27 seq.
- Washington Suburban Sanitary District; pipe, deLavaud, 220 seq.
- Waste; education re, 92
 metering and, 462 seq.
 reduction; methods, 461 seq.
 pitometer survey and, 285, 306 seq., 456 seq.
see Meter reading
- Water analysis; for boiler purposes, 433
 carbon, 389
 carbon dioxide, 122 seq.
 chlorine, free; o-tolidin; ammonia and, 349
 reagent, preparation, 121 seq.
 sensitivity, 121
 starch-iodide, sensitivity, 121
 committee; report, 112 seq.
 work, status, 596 seq.
 hardness, soap, accuracy, 573
 H-ion concentration; colorimetric, accuracy, 575
 potentiometric; 569 seq.
 calomel electrode, 577
 hydrogen electrode; 575 seq.
 poisoning, 577 seq.
 quinhydrone electrode; limitations, 579 seq.
 recording, 581 seq.
 tungsten electrode, pH-voltage relationship, 578
 mineral, 119
 nitrogen; as albuminoid ammonia, value, 389 seq., 393 seq.
 as free ammonia; aspiration, 389, 393
 direct nesslerization, 388 seq.
 distillation, accuracy, 388 seq., 393 seq.
 Kjeldahl, accuracy, 390
 as nitrate, aluminum reduction, error in, 393 seq.
 oxygen demand; 124 seq.
 nitrite and dilution, accuracy, 125
 oxygen dissolved; Levy, 120
 Winkler, iron and, 120
 phenol; chlorination taste, correlation with, 343 seq.
 Folin-Denis, accuracy, 125
 scale forming constituents, calculation, 262
 turbidity, 119 seq.
see Bacteria, spore forming; Bacterium coli test; Leptospirae; Microscopic examination
- Water, gratuitous; Butte, Mont., 385
 Detroit, Mich., 300
 unfairness of, 298
- Water hyacinth; color and, 230
- Water measuring devices; level gauge, 6
- Water quality; mineral constituents, limits, U. S. P. H. S., 261
 turbidity, limits, 261, 704, 714
- Water rights; rates and, 511
- Water, unaccounted for; data, various cities, 309 seq.
see Leakage
- Water, underground; pumping, 318 seq.

- storage, 320 seq.
see Well
- Water works; in United States; cost per capita, 106
number, 59
see Accounting; Financing; Fire protection; Pumping station; Utilities; etc.
- Wauchula, Fla.; water supply, 48
- Webster, Fla.; water supply, 47
- Weil's disease; *see* Jaundice
- Well; bacteria, freeing of, 85
drilling, control of, 320
pumping; 318 seq.
air-lift; 468 seq.
leakage, importance, 469
theory, 469 seq.
water level drop, 329
see Water, underground
- West Carrollton, O.; flood protection, 734
- West Frankfort, Ill.; rainfall, 584
- West Palm Beach Water Co.; water purification, 41, 46
- White Springs, Fla.; water supply, 39
- Wichita Falls, Tex.; consumption, 198
- Wiersdale, Fla.; water supply, 47
- Wilksburg, Pa.; *see* Pennsylvania Water Co.
- Williston, Fla.; water supply, 47
- Wilmington, Del.; consumption, 198
- Wilmington, N. C.; typhoid, 763 seq.
- Winamac, Ind.; water supply, 331 seq.
- Winnipeg, Man.; fire protection charges, 653, 659
hydrant inspection, 659
taxation, 664
- Winona Lake, Ind.; typhoid and cross-connections, 332
- Winter Garden, Fla.; water supply, 47
- Winter Haven, Fla.; water supply, 47
- Winter Park, Fla.; water supply, 46
- Wolf Creek; flood control, 727 seq.
- Wood distillation waste; chlorination taste and, 337 seq.
- Woodstock, Ont.; fire protection charges, 653
- Wool waste; nitrogen content and oxygen demand, 61
- Woonsocket, R. I.; consumption, 198
- Worcester, Mass.; consumption, 198
typhoid, 761 seq.
- Yonkers, N. Y.; consumption, 198
typhoid, 761 seq.
- Youngstown, O.; consumption, 198
typhoid, 763 seq.
- Zeolite; *see* Boiler feed; Railroad supplies; Softening
- Zephyrhills, Fla.; water supply, 47

AUTHOR INDEX

- ANDREWS, GEO. C., the Buffalo water works, 279 seq.
- BAYLIS, JOHN R., preliminary experiments on the treatment of Lake Michigan water for Chicago, 710 seq.
- BEECH, F. B., meter over-registration complaints, 92 seq.
- BENNETT, C. S., flood control in the Miami Valley of Ohio, 727 seq.
- BRUSH, WM. W., disinfection of new water mains, 79 seq.
obituary of Merritt Haviland Smith, 127 seq.
experiences with storage reservoirs at low level, 699 seq.
- BURGESS, PHILIP, cement-lined pipe, 87 seq.
- BUSWELL, A. M., *see* Neave, S. L., and Buswell, A. M.
- CALVERT, C. K., Indiana Section meeting, 787 seq.
- CARROLL, EUGENE, the water works plant of Butte, Mont., 371 seq.
- CARTWRIGHT, WM., equitable charges for automatic sprinkler connections, 64 seq.
- CHAMBERS, JOHN, diversion of municipal water works funds, discussion, 300 seq.
- CHRISTIE, A. G., embrittlement of steel, 174 seq.
- COHEN, CHESTER, chlorination for algae control, 444 seq.
- CURTIS, J. E., increasing the water supply of Washington, D. C., 27 seq.
- DANIELS, JOS. J., the Indianapolis Water Co., rate case, 505 seq.
- DARROW, W. E., investigations of the northern end of Lake Okeechobee for development of potable water supply, 227 seq.
- DOBBIN, R. L., charges for public fire protection, 647 seq.
- DUFFY, R. E., a general rule for making extensions, 673 seq.
- DUGAN, F. C., Kentucky Section meeting, 604 seq.
- DUNHAM, H. F., specifications for cast iron pipe, discussion, 600 seq.
- ELLMS, J. W., *see* LEVY, A. G., and ELLMS, J. W.
- ENGEL, M. L., Illinois Section meeting, 610 seq.
- FAGG, J. H., meter maintenance methods, 464 seq.
- FENKELL, GEO. H., diversion of municipal water works funds, discussion, 304 seq.
- FILBY, E. L., water supplies of Florida, 37 seq.
Florida Section meeting, 396 seq.
- FINCH, LEWIS S., water shortage in Indiana, 327 seq.
- FLEMING, JOHN D., the use of the Dorr clarifier in water treatment, 215 seq.
- FLENTJE, MARTIN E., calcium and magnesium hydrates as coagulating agents, 253 seq.
- FOOTE, H. B., Montana Section meeting, 489 seq.
- FOULK, C. W., present knowledge of foaming and priming of boiler water, with suggestions for research, 160 seq.
- FOX, CHAS. L., experiences with leadite, 94 seq.
- FUERTES, JAS. H., the Denver filter plant, 538 seq.
- FULKMAN, J. A., and TAYLOR, E. J., iron removal plant at Selma, Ala., 69 seq.
- FULLERTON, HOWARD R., the water supply problems of Tennessee, 746 seq.
- GALLAHER, W. U., dissolved oxygen changes during filtration, 476 seq.
- GIBSON, JAS. E., a large elevated storage tank at Charleston, S. C., 291 seq.
diversion of municipal water works funds, discussion, 303 seq.
- GINTER, R. L., spore bearers in the Spavinaw water supply, 591 seq.

- GORMAN, ARTHUR E., cross connection policies, 553 seq.
- GREER, WILLARD N., AND PARKER, HENRY C., potentiometric determination of hydrogen ion concentrations in boiler waters, 569 seq.
- GROBBEL, D. C., diversion of municipal water works funds, discussion, 296 seq.
- GROBBEL, D. C., AND SMITH, HAL., complaints—how handled, 98 seq.
- HALE, HARRISON, city water supplies in Arkansas, 261 seq.
- HALL, GEO. L., more water for New York City—a review, 243 seq.
- HAMLIN, GEO. W., the Baldwin Filtration Plant, 420 seq.
- HARRISON, LOUIS B., super-chlorination of chlorophenol tastes, 336 seq.
- HAWLEY, W. C., municipal fire hydrant rental, 96 seq.
- HINMAN, JACK J., JR., Iowa Section meeting, 129 seq.
- HOOVER, CHARLES P., water softening as an adjunct to water purification, 751 seq.
- HOWARD, NORMAN J., Report of Metropolitan Water Board of London—an abstract, 235 seq.
- HUDSON, LEO, AND RICHARDS, A. J., cost of operating motor driven centrifugal pumps at McKeesport, Pa., 356 seq.
- JENKS, HARRY N., electrolytic chlorination at Sacramento filtration plant, 514 seq.
- JOHNSON, S. C., water treating problems in railroad practice, 429 seq.
- JOHNSON, W. SCOTT, Missouri highway sanitation problems and program, 435 seq.
- KEPNER, DANA E., Rocky Mountain Section meeting, 608 seq.
- KNOUSE, HOMER V., cost accounting for pipe laying jobs, 368 seq.
- KNOWLES, CLARENCE R., the probable future development of railway water treatment, 51 seq. pretreatment of boiler feedwater, 151 seq.
- LAWLOR, FRANCIS D. H., the franchise of the Citizen's Water Co., Burlington, Ia., 75 seq.
- LEE, CHAS. H., water consumption for various purposes in terms of depth and area, 193 seq.
- LE PRINCE, J. A., mosquito control in relation to impounded water supply, 31 seq.
- LEVY, A. G., AND ELLMS, J. W., the hydraulic jump as a mixing device, 1 seq.
- LONGLEY, F. F., carrying capacity of pipes, discussion, 103 seq.
- MCAMIS, J. W., prevention of phenol taste with ammonia, 341 seq.
- MAFFITT, M'KEAN, notes on pumping and water works operation, 468 seq.
- MAGERSTADT, PAUL E., California Section meeting, 263 seq.
- MALISHEWSKY, N., experiments in the hydraulics of filter underdrains, 667 seq.
- MAXWELL, D. H., rehabilitation of the Racine water works, 106 seq.
- MULHOLLAND, WM., the proposed aqueduct from the Colorado River, 409 seq.
- NEAVE, S. L., AND BUSWELL, A. M., the significance of nitrogen determinations in sanitary analysis, 388 seq.
- OSBORN, L. C., phenol tastes in chlorinated water, 586 seq.
- PARKER, HENRY C., *see* GREER, W. N., AND PARKER, H. C.
- PEETS, ELBERT, the Cleveland reservoir, 417 seq.
- PRACY, GEO. W., solving the seagull problem in San Francisco, 466 seq.
- RICHARDS, A. J., *see* HUDSON, L., AND RICHARDS, A. J.
- RIDGWAY, ROBERT, protecting the water supply system in subway construction in New York City, 629 seq.
- RUE, J. A., electrically driven pumping stations and peak loads, 365 seq.
- SANDERSON, A. U., Canadian Section meeting, 788 seq.
- SERKES, MEYER, the pitometer survey in the improvement and

- maintenance of a distribution system, 456 seq.
- SIEMS, V. BERNARD, municipal water supplies and the effect of trade wastes in relation to the use of water in power plant practice, 190 seq.
- SIMPSON, J. H., consumers reactions to various systems of rates, discussion, 89 seq.
- SMITH, HAL., *see* GROBBEL, D. C., AND SMITH, HAL.
- SMITH, J. WALDO, progress report of committee on standard form of contract, 110 seq.
- STEWART, E. B., corrosion in a water supply system and methods of protection, 557 seq.
- TAYLOR, E. J., *see* FULKMAN, J. A., AND TAYLOR, E. J.
- TRAUGER, GEO. W., underground waters and pumping therefrom, 318 seq.
- VEATCH, N. T., JR., stream pollution and its effects, 58 seq.
- WALKER, ISAAC S., essential daily log data in the pumping station, 351 seq.
- WHITE, H. L., amount of water available from impounding reservoirs, 583 seq.
- WILSON, CARL, the biological control of impounding reservoirs, 247 seq.
- WOLFE, THOS. F., use of two water mains in wide streets, 740 seq.
- WOLMAN, ABEL, impounded waters and malaria—editorial comment 481 seq.
a model bond law—editorial comment, 602 seq.

INDEX TO ABSTRACTS

I. AUTHORS

- ADAMS, ALTON D., 778
 ALLGEYER, JOHN, 145
 ALLIEVI, LORENZO, 626
 ALSTERBERG, G., 270
 American Railway Engineering Association, 784
 American Society for Testing Materials, 271
 ANNIS, R. K., 614
 ARLOING, F., SEMPE, and CHAVANNE, 500
 ARNOLD, LLOYD, 502
 ATEN, A. H. W., and VAN GINNEKEN, P. J. H., 405
 AUB, JOSEPH C., MINOT, A. S., FAIRHALL, LAWRENCE T., and REZNICKOFF, PAUL, 408
- BABLIK, HEINZ, 624
 BAILEY, J. P., 773
 BAILEY, PAUL, 772
 BAKER, L. L., 614
 BARDWELL, R. C., 625
 BARNES, H. T., 495
 BARR, W. M., 782
 BARR, W. M., and SAVIDGE, R. W., 398
 BAUDISCH, OSKAR, and WELO, L. A., 272
 BAUER, O., 272
 BAUMANN, R., 149
 BAYLIS, JOHN R., 402, 501, 774
 BEHRMAN, A. S., 402
 BELLUZZO, GIUSEPPE, 785
 BENHAM, WEBSTER L., 143
 BETTS, C. A., 268
 BIGGAR, L. H., 150
 BLACHER, C., 274
 BLEE, C. E., 137, 138
 BOGERT, LATHROP, *see* FLINN, A. D.
 BOSART, L. W., *see* ROBBINS, H. B.
 BÖTTGER, P., 408
 BOYD, D. K., 778
 BRAKENRIDGE, C., 271
 BREMNER, A. G., 785
 BRIGGS, B. A., 614
 BROWN, C. C., 496
 BROWN, HUGH F., 778, 779
- BROWNLIE, DAVID, 402
 BUNDSCHU, FELIX and LUDIN, ADOLF, 626
 BUTLER, JOE B., 626-7
- CAGLIOTI, V., *see* ZAMBONINI, F.
 CAMERON, A. B., 498, 499
 CAILOL, R., 273
 CALKINS, D. J. F., 779
 Canada, Department of Interior, 401
 CARMICHAEL, D. C., 277
 CAROBBI, G., *see* ZAMBONINI, F.
 CARROLL, EUGENE, 777
 CARSTANJEN, MAX, *see* KOCH, A.
 CHAVANNE, *see* ARLOING, F.
 CHOUGHAK, D., *see* POUGET, I.
 CHRISTIANS, GEO. W., 140
 CLARK, F. W. G., 613
 CLAUSEM, I. M., 143
 COCHRANE, D., 407
 COLBURN, C. E., 617
 CONKLIN, HAROLD, 493
 CONLON, W. T., 617
 Connecticut State Department of Health, 399
 CONVERSE, E. M., 613
 COUGHLAN, R. E., 625
 COSTILL, H. B., 400
 CROCKER, S., 617
 CUSHING, A. T., 777
- DANIELSON, W. A., *see* TYLER, R. G.
 DAVIDSON, J. R., 776
 DAVIS, ARTHUR P., 773
 DEEDS, J. F., and WHITE, W. N., 493
 DELECOURT, J., 272
 DIÈNERT, F., 623
 DIJKHOORN, J. C., 624, 774
 DITTOE, W. H., et al., 500
 DONALDSON, WELLINGTON, 497
- Eagle-Picher Lead Co., 621
 EBBERTS, A. R., 618
 EIFFERT, C. H., 620
 ELKELES, G., 147
 ELLMS, J. W., 136, 277
 ENSLOW, LINN H., 500
 ESS, T. J., 276

- FAIRHALL, LAWRENCE T., *see* AUB, J. C.
 FELCH, D. H. W., 398
 FERGUSON, ELMER L., *see* HATCHER, M. P.
 FIGG, E. F., 622
 FILBY, E. L., 399
 FLENTJE, MARTIN E., 500
 FLINN, A. G., WESTON, R. S., and BOGERT, L., 503
 FRANKFURT, J., 406
 FRENCH, R. DE L., and WOOD, F. M.
 FROBOESE, 277
 FUJIHARA, T., 405

 GAGE, STEPHEN DE M., 275
 GALIVIALO, M. J., *see* VLADIMIRO, G. E.
 GANAPATI, S. V., 271, 614
 GAYTON, LORAN D., 140
 GERSTEIN, H. H., 776
 GILES, R. T., 501
 GILLETTE, HALBERT P., 499
 VAN GINNEKEN, P. J. H., *see* ATEN, A. H. W.
 GIRRARD, RÉNÉ, 274
 GLEASON, E. P., and WATSON, C. F., 147
 VON GONZENBACH, W., 273
 GOODNOUGH, X. H., 276
 GRAF, AUGUST V., 145, 268
 GRAF, OTTO, *see* HUNDESHAGEN, F.
 GRIMLEY, K. W., *see* HARDENBERGH, W. A.
 Griscom-Russell Co., 404
 GROECK, M., 625
 GROH, 408
 GROSS, C. D., 400
 GRÜN, RICHARD, 408
 GUNDERSON, L. O., 784
 GUTH, J., 406

 HABERMAYER, G. C., 148, 502
 HAGGLUND, L. F., 613
 HALE, FRANK E., 277
 HALL, R. E., 149
 HALL, FRED C., 498
 HALMOS, EUGENE E., 626
 HANLEY, J. P., 620
 HANSEN, PAUL, 143, 498
 HARDENBERGH, W. A., and GRIMLEY, K. W., 148
 HAROLD, C. H. H., 501
 HARRIS, IRVING C., 146
 HATCHER, M. P., 270
 HATCHER, M. P., and FERGUSON, E. L., 142
 HATFIELD, W. H., 403
 HAYDEN, T. A., 143

 HAZEN, ALLEN, 271
 HEITZMANN, JAMES L., 622
 HELLAND, R. O., *see* JONES, B. E.
 HENRY, D. C., 780
 HETTERSCHIJ, C. W. G., 405
 HIGGINS, H. K., 777
 HILL, NICHOLAS S., Jr., 275
 HINDS, JULIAN, 779
 HOCHEDER, FRANZ, 272
 HOLMES, J. ALBERT, 138
 HOOVER, CHAS. P., 498
 HOWARD, N. J., 774
 HOWARD, N. J., and THOMPSON, R. E., 133
 HOWSON, L. R., 141
 HUBBARD, C. L., 273
 HUNDESHAGEN, F., GRAF, O., and KLEINLOGEL, A., 408
 HUTH, F., 621

 Illinois State Department of Health, 400
 IRVING, S. G., *see* LEWIS, W. B.

 JACOMETTI, A. W. A., 272
 JARVIS, C. S., 137
 JAKKULA, A. A., 619
 JENKINS, J. D., 407
 JENSEN, JOHN A., 138, 145
 JEYNES, P. H., 614
 JONES, B. E., and HELLAND, R. O., 493
 JONES, L. S., 400
 JONES, WILLARD B., 142
 JOSSE, E., 149

 VON KÁLMÁN, OTTO, 274
 KELSEY, JOHN W., 144
 KIERSTED, WYNKOOP, Jr., 267
 KLEINLOGEL, A., *see* HUNDESHAGEN, F.
 KNOWLES, C. R., 783
 KOBÉ, W. H., 267
 KOCH, ALEXANDER, and CARSTANJEN, M., 626
 KOYL, C. HERSCHEL, 407
 KRÖHNKE, 501

 LeBosquet, M., Jr., *see* TYLER, R. G.
 LEDOUX, J. W., 782
 LEE, CHAS. H., 266
 LEGENDRE, R., 785
 LEVENS, A. S., 620
 LEWIS, W. B., and IRVING, S. G., 625
 LEBREICH, E., 620
 LIPPINCOTT, J. B., 140
 LOWE, T. W., 150
 LUDIN, ADOLF, *see* BUNDSCHU, F.
 LUND, A. F. R., 403

- MAASS, EMIL, 408
 MACMILLAN, H. J., *see* ROBBINS, H. B.
 MARKUS, B., 269
 MASSINK, A., 277
 MAYNARD, E., 137
 McCULLOUGH, J. W. S., 501
 McDONNELL, M. E., 406
 McMILLAN, F. R., 136
 McNAMEE, R. L., 148, 622
 MEACHAM, W. M., 781
 MELLER, KARL, 403
 MERRIMAN, THADDEUS, 139
 MILES, W. M., 408
 MILNE, ALEXANDER, 775
 MINOT, A. S., *see* AUB, J. C.
 MISKELLA, W. J., 622
 MIX, A. E., and SALE, J. W., 775
 MOHR, OTTO, 273
 MONK, W. W., 136
 MOORE, J. C., 149
 MORGENSTERN, EMIL, 785
 MOSS, F. J., 617
 MUER, 277

 National Electric Light Association, 406
 New Jersey State Department of Health, 400
 New York State Department of Health, 147
 NOLL, H., 404
 North Carolina Department of Conservation and Development, 493

 O'BRIEN, J., 497
 O'CONNOR, JAMES A., 148
 OKAZAKI, B., 781
 OLSON, REUEL LESLIE, 785
 OLSZEWSKI, W., 277

 PARIS, G., 273, 402
 PARKER, F. Y., 619
 PARR, S. W., and STRAUB, F. G., 398, 784
 PARSONS, W. H., 785
 Paterson Engineering Co., Ltd., 785
 PECK, W. P., 781
 Pennsylvania Department of Health, 399
 PIERCE, RALPH, 143
 POUGET, I., and CHOUGHAK, D., 403
 POWELL, S. T., 615, 616
 POWNALL, W. A., 150, 784
 PRACY, GEO. W., 141
 PRITCHARD, JOHN C., 142, 267
 PROST, EUG., 404

 REAGEL, F. V., 269
 REID, C. R., 617

 REIGELUTH, R. J., 146
 REINBOLD, HERMAN, 404
 RESSLER, CHAS. T., 784
 REZNIKOFF, PAUL, *see* AUB, J. C.
 RILEY, R., *see* SWEENEY, O. R.
 RISCH, C., 623
 ROBBINS, H. B., MACMILLAN, H. J., and BOSART, L. W., 273
 ROGERS, A. W., 776
 ROOF, S. E., 147
 ROSS, CLYDE P., 148
 RUSSELL, R. P., 403

 SAITO, MAKOTA, *see* UTIDA, Y.
 SALE, J. W., *see* MIX, A. E.
 Salisbury Bradshaw and Taylor, 771
 SAVIDGE, R. W., *see* BARR, W. M.
 SAVILLE, CALEB MILLS, 496
 SAYERS, W. W., 615
 SCHNARR, WILFRED, 780
 SCHOCH, E. P., 626
 SCHÖNBRUNNER, FRANZ, 501
 SCHWARZ, M., 150, 407
 SCOBIEY, FRED C., 136
 SCOFIELD, CARL S., 623
 SCOTT, L. C., 399
 SEMPE, *see* ARLOING, F.
 SETON, A., 624
 SHERMAN, CHAS. W., 495
 SHUEY, GEO. R., 619
 VAN SCOYOC, H. S., 773
 SIDNEY, L. P., 405
 SIEMS, V. BERNARD, 621
 SIMMONS, W. H., and SUTTON, F. C., 273
 SMIT, JAN, 404
 SMITH, B. A., 782
 SMITH, HAROLD D., 148
 SMITH, WM. E., 500
 SNELL, F. D., 403
 SPELLER, FRANK N., 150
 SPLITTERGERBER, A., 404, 624
 SPURR, HENRY C., 785
 STAS, M. E., 270
 STAUS, A., 785
 STEELE, I. C., 144
 STEPHENS, C. T., 274
 STERN, A., 624
 STEVENS, J. C., 772, 779
 STONE, ORMOND A., 771
 STRAUB, F. G., *see* PARR, S. W.
 STRAUB, LORENZ G., 774
 STREETER, H. W., 618
 STURDEVANT, C., 625, 783
 SUDLER, CHAS. E., 782
 SUTTON, F. C., *see* SIMMONS, W. H.
 SVERDRUP, L. J., 778
 SWEENEY, O. R., and RILEY, R., 626
 SWOBODA, JULIUS, 620
 SYKES, GLENTON G., 771

- TAYLOR, F. S., 626
 TAYLOR, W. A., 277-8
 TELLER, L. W., 139
 TENNEY, E. H., 625
 THIEM, G., 405
 THIENEMANN, AUGUST, 402
 THOMAS, HAROLD A., 779
 THOMPSON, M. DEKAY, 274
 THOMPSON, RUDOLPH E., *see*
 HOWARD, N. J.
 TREMBLAY, THOMAS, 621
 TYLER, R. G., DANIELSON, W. A.,
 and LEBOSQUET, M., JR., 495

 ULSAMER, O., *see* WEICHARDT, W.
 UTIDA, YUHATIRÓ, and SAITÓ,
 MAKOTA, 401

 VAN, neglected for indexing purposes
 VEDDER, E. B., 272
 VOGEL, J. H., 273
 VON, neglected for indexing purposes
 VLADMIRO, G. E., and GALIVIALO,
 M. J., 405

 WADLEIGH, GEO. R., 777

 WAGBER, D. R. P., 626
 WALKER, STANTON, 137
 WATSON, C. F., *see* GLEASON, E. P.
 WEICHARDT, W., and ULSAMER, O.,
 403
 WELO, L. A., *see* BAUDISCH, O.
 WESTON, ROBT. SPURR, *see* FLINN, D.
 WHERRY, WM. M., JR., 494
 WHITE, W. N., *see* DEEDS, J. F.
 WIEGLAND, GUSTAV, 273
 WIEGLER, P., 623, 625
 WILSON, R. C., 499
 WINTERMEYER, 149
 WITKIN, ZARA, 621
 WOLF, JOSEPH, 613
 WOLFE, THOS., 496
 WOLFF, HANS, 270, 621
 WOLMAN, ABEL, 277
 WOOD, F. M., *see* FRENCH, R. DEL.
 WUESTE, R. C., 270

 YODER, J. D., 625
 YOUNG, J. W., 405

 ZAMBONINI, F., CAROBBI, G., and
 CAGLIOTI, V., 501

INDEX TO ABSTRACTS

II. SUBJECTS

- Accounting; methods and, 148
see Depreciation; Interest; Law; Utility
- Administration; *see* Books, New
- Aëration; cooling and, 147
 Liverpool, Eng., and, 776
 spray and; wind losses and, 776
- Aganano, Italy; mineral waters and, 501
- Air-Lift; *see* Pump
- Alabama; Jefferson County and; water works and, 148
- Alamo Canal; scour and, 771
- Albany, N. Y.; filter plant reconstruction and, 271
 typhoid and; litigation and, 147
 water supply, new, and, 147
- Alberta, Can.; drainage and; data and, 401
- Albuquerque, N. M.; water supply and, 137
- Alcement; *see* Cement
- Aledo, Ill.; well, deep, and, 502
- Algae; control and, 499
 tastes and, 499
- Algiers; radioactivity and, 403
- Alouette, B. C.; *see* Dam
- Alum; *see* Chemical
- American Society for Testing Materials; standards, tentative, and, 271
- Analysis; conversion factors and, 782
see Concrete; Mortar; Turbidity
- Calcium and; magnesium separation and, 404
 titration, direct, and, 626
- Chlorine, Free, and; apparatus, portable, and, 776
 o-tolidin and; hydrogen-ion concentration and, 277
 sunlight and, 133
- Hardness and; titration method and, 626
- Hydrogen-Ion Concentration and; electrode, Lehmann, and, 405
 electrode, special, and, 405
 potentiometer, special, and, 405
- Magnesium and; titration, direct, and, 626
- Nitrite and; removal and, 270
- Oxygen Dissolved and; micro-test and, 623
 nitrite removal and, 270
- Phenol and; color tests and, 133-4
- Sulfate and; titration and, 626
- Androscoggin River; Gulf Island dam construction and, 780
- Aqueduct; Washington, repairs and, 147
- Arlington County, Va.; water supply and, 148
- Artesian; *see* Well
- Asphalt; grout and; dam leakage control and, 140
- Athens, Greece; pipeline and, 620
 reservoirs and, 620
- Auperle Reagent; galvanized coatings and, 624
- Aurora, Ill.; wells, deep, and, 502
- Bacteriological Examination; bacteriophage and; interference and, 502
- Bacteriophage; bacteriological examination and, 502
 river and sea water and, 500
 surface water and, 502
- Baltimore, Md.; cement prehydration and, 142
 valve boxes, concrete, and, 621
- Bank; protection and; Fountain River, Colo., and, 776
 Ishikari River, Japan, and, 781
 Sacramento River and, 772
 West Indies and, 776
see Mattress; Retard
- Banta Carbona, Cal.; irrigation and; pumping plant and, 772
- Batiscan River; hydro-electric plant and; dam and, 776
- Bauer Reagent; galvanized coatings and, 624
- Bay City, Mich.; water works, new, and, 136
- Belgium; water supply and, 495
 wells, artesian, and, 272
- Bentonite; zeolite, artificial, and, 404

- Boiler; evaporation and; calculation and, 407
 locomotive; sludge removal and, 783
 plate and; strength and, 405
 pressures, increasing, and, 405
 seams and; alkali concentration and, 149
- Boiler Compound; cleaning and; formula and, 781
- Boiler Corrosion; arsenic and, 784
 Canadian Pacific Railway and, 150
 discussion, general, and, 150, 616, 784
 embrittlement and, 398, 407, 615, 784
 sulfate: carbonate ratio and, 398, 615
 zeolite and, 783
 factors, principal, and, 617, 625
 magnesium chloride and, 273
 oxygen and, 399, 616-17, 624, 784
 pitting and, 150
 causes and, 784
 prevention and, 407, 784
 prevention and, 273, 398-9, 406, 617, 784
 scale and, 399
 sodium salts and, 399
see Corrosion; Iron, Corrosion and
- Boiler Feed Water; air and; pumps and, 624
 bibliography and, 404
 control and; necessity and, 624
 de-aëration and, 404, 616
 discussion, general, and, 406
 evaporators and; types and, 616
 filtration and, 150
 excelsior and, 782, 783
 heaters and, 624
 Dabeg type and, 783
 open type and, 399
 pump type and, 149
 impurities and, 149
 lime and, 624
 oil elimination and, 500, 624, 774
 oxygen recorder and, 406
 pressures, high, and, 624, 625
 railroads and, 624-5, 626
 Riwoq process and, 625
 treatment and, 273, 404, 614, 623, 624, 625, 626
 acid and, 398, 407
 distillation and, 141
 hot process and, 625
 mechanical, 623
 sodium aluminate and, 406
 supplies, small, and, 402
 zeolite and; experience and, 783
- Boiler Priming; control and, 615
 damage and, 615
 sodium carbonate and, 399
 sodium chloride and, 277
 sodium hydroxide and, 399
 suspended solids and, 615
- Boiler Scale; deconcentrator and, 497, 625
 oil and, 407
 pressures, high, and, 407
 prevention and, 273, 406, 407
 linseed and, 407
 properties, physical, and, 273
- Boiler Water; analysis and; interpretation and, 277
 concentration and, 399, 407
 de-concentration and; economy and, 497, 625
 "filtrator" device and, 625
 organic matter and, 277
 priming and, 277, 399
 sodium acetate and, 277
 carbonate and; hydrolysis and, 277
 chloride and, 277
 formate and, 277
 sulfate and, 277
 sulfate:carbonate ratio and, 625
 treatment and, 149, 624
 trisodium phosphate and, 625
- Books, New:
 The ABC of Hydrogen Ion Control, 277
 Die Abwässer aus der Kaliindustrie, 273
 Der Beton, 408
 The Chemistry of Power Plant, 408
 Chlorination and Chlorine Absorption of Water, 277
 The Colorado River Compact, 785
 La Concentration en Ions Hydrogène de l'Eau de Mer, 785
 Descriptive Bibliography on Oil and Fluid Flow and Heat Transfer in Pipes, 626-7
 Druckrohrleitungen: Berechnungs- und Konstruktionsgrundlagen der Rohrleitungen für Wasserkraft- und Wasserversorgungsanlagen, 626
 Einflüsse auf Beton, 408
 Der Genauigkeitsgrad von Flügelmessungen bei Wasserkraftanlagen, 785
 Guiding Principles of Public Service Regulation. Vol. 3, 785-6
 Korrosion und Rostschutz, 408
 Lead Poisoning, 408
 Die Mineralquellen und Kurmittel des Iodbades Tölz, mit be-

- sonderer Berücksichtigung ihrer Anwendungsweise, 785
- Neuere Volksbäder, 408
- Public Ground Water Supplies in Illinois, 502
- Theory of Water Hammer, 626
- Von der Bewegung des Wassers und den dabei auftretenden Kräften: Grundlagen zu einer praktischen Hydrodynamik für Bauingenieure, 626
- Wasserversorgung und Brunnenbau, 408
- Water Sterilization by Gaseous Chlorine, 785
- Waterworks Administration: Being a practical Guide to the Solution of the many Problems met with in the Business Management of a Public Water Supply Undertaking and Containing some Suggestions for the Amendment of Waterworks Law, 785
- Waterworks Handbook of Design, Construction, and Operation, 503
- Boston, Mass.; water supply, additional, and, 145
- Brass; corrosion and, 150, 407
- Britain; softening and, 402
- water supply practice and, 495
- British Columbia; drainage data and, 401
- Bucyrus, Ohio; algae control and, 499
- dry-feed control and; savings and, 498
- Buffalo, N. Y.; cross-connections and; elimination and, 780
- Calaveras; dam; failure and; taxes and, 774
- Calcium Chloride; *see* Concrete
- California Oregon Power Co.; turbine runner replacement and, 138
- Cambridge, Mass.; head loss experiments and, 495
- Canada; water power and; resources and, 401
- Canadian Pacific Railway; boiler corrosion and, 150
- Carbon Dioxide; wells, coastal, and, 401
- Carbonation; Tampa, Fla., and, 275-6
- Catalysis; water and; iron, active, and, 272
- Cedar River; Seattle, Wash., and; water supply and, 135
- Cement; Alcement; tests and, 403
- lime-silica index and, 139
- quick-hardening, 274
- setting time and; indicator and, 619
- specifications and; Missouri and, 269
- sugar and, 621
- see* Concrete
- Charleston, S. C.; tank, elevated, large, and, 141-2
- Chaudfontaine, Belgium; radioactivity and, 404
- Chemical; dry-feed control and; economy and, 498
- transport, pneumatic, and, 138
- Chimney; practice, good, and, 778
- Chloramine; field experiments and, 501
- Chlorination; applications, manifold, and, 500
- chlorine absorption and, 277
- direct and indirect, 277
- electrolytic, Williams, and, 619
- swimming pools and, 147
- tastes and; hydrogen-ion concentration and, 134
- iodide and, 133
- phenols and, 133-4
- super- and de-chlorination and, 133-4
- Toronto, Ont., and, 133-4
- see* Books, New; Chloramine
- Chlorine; therapy and, 272
- Chlorine Absorption; chlorination and, 277
- Clarifier; OMS purifier and, 273
- Springfield, Ill., and; concrete arch supports and, 774
- Coagulation; alum and aluminate floc and; filters and, 496
- hydrogen-ion concentration and, 278
- Coal; crushers and, 615
- storage and; combustion, spontaneous, and, 617
- losses and, 617
- method and, 617
- Color; removal and; sulfur dioxide and, 275
- Colorado River; compact and, 785
- hardness and, 623
- Los Angeles and, 136
- purification and; El Centro and, 146
- salinity, increasing, and, 623
- turbidity and, 146
- see* Books, New
- Colorado Springs, Colo.; hydroelectric system and, 618-19
- water supply and, 618-19
- Columbus, Ohio; softening and; split treatment and, 139, 498-9
- Combustion, Spontaneous; *see* Coal
- Compensation Water; reservoirs and, 496

- Concentration; time and; equation and, 274
- Concrete; aggregate and; control and, 137, 145, 501, 621
alkali soils and, 771
asphaltic; bitumen determination and, 618
calcium chloride and, 620, 773
cement prehydration and; advantages and, 142
cofferdam seal and, 267
measurement and, 777
quicksand control and, 146
samples and; cylinders and, 619
specifications and; water: cement ratio and, 136
strength, early, and, 773
sugar and, 621
sulfur treatment and, 267
vibrothitic process and, 139
waste; flushing and, 780
water control and; strength and, 501, 621
workability and; tests and, 776
see Books, New; Cement; Gunite; Mortar
- Condenser; cleaning and, 625
corrosion and, 150, 407
economies, possible, and, 614
scaling tools and, 407
surface; replacing jet, and, 147
testing and, 617
waterworks type and, 267
- Conductivity; hardness and; calculation and, 269
- Conservancy; *see* District
- Coolidge Dam; design and, 143
- Cooling; aëration and, 147
- Copper; endurance tests and, 779
- Corpus Christi; water works and; re-vamping and, 772
- Corrosion; condenser tubes and, 150
prevention and; sodium silicate and, 403
review, general, and, 272
see Boiler Corrosion; Condenser; Iron, Corrosion and
- Cresol; chlorination and; tastes and, 133-4
- Cross-Connections; prohibition and; Buffalo, N. Y., and, 780
sanitary hazard and, 399
- Cutting; illuminating gas and, 618
pipes and; guide and, 778
under water; oxy-electric, 613
- Czechoslovakia; water power development and, 613
- Dallas, Texas; flood protection and; Trinity River and, 619
water warm, and; cooling and, 147
- Dam; Alouette, B. C.; construction and, 137
spillway and, 138
- Androscoggin River and; winter construction and, 780
- arch; abutments and; failures and, 775
deflection and; experiments and, 782
thin section; Norman Flat, Arizona, and, 138
- Batiscan River and, 776
- Calaveras Creek; failure and, 774
- Coolidge; multiple-dome type and, 143
- crest gates and, 777
- dome, multiple, and, 143
- earth; old; Pequannock River, N. J., and, 138
shrinkage and, 267, 778
- Exchequer; gates and, 777
- gravel; grasses, protective, and, 620
- ice and; protection and; gunite and, 777
- leakage control and; Hales Bar, Tenn., and, 140
- Pacoima, Cal.; height and, 145
- St. Francis; Los Angeles and, 136
- San Gabriel River; world record and, 145
- scouring and; combating and, 144
- De-aëration; boiler feed water and, 404
- De-chlorination; sulfur dioxide and, 134
see Chlorination
- Decolorization; *see* Color
- De-Concentrator; boiler water and, 497, 625
- Delaware and Hudson R. R.; Dabeg heater and; economy and, 783
- Delhi, Mich.; dam failure and, 267
- Denver, Colo.; flood control and; censures and, 139
see Marston Lake; Moffat Tunnel
- Depreciation; principles and, 494
- Detroit; filter plant, experimental, and, 143
- Diesel Engine; world's largest, 615
- District; conservancy; Illinois and, 498
Miami, Ohio, and, 620
- Diversion; compensation and, 496
- Dropping-Bottle; calibration and, 274
- Earthquake; San Francisco area and; hazards and, 266
- East Bay Water Co.; *see* Mokelumne River
- East Liverpool, Ohio; typhoid reduction and, 780

- Economizer; present practice and, 624
- El Centro, Cal.; water supply and; Colorado River and, 146
- El Paso, Texas; water supply and, 268
- Elk City, Okla.; water supply and cost and, 143
- Embrittlement; *see* Boiler Corrosion
- Ems, Germany; sewage problems and, 404
- tastes and, 404
- England; *see* Britain
- Escanaba, Mich.; tastes, creosote, and; elimination and, 622
- Evaporator; types, various, and, 616
- Excavation; *see* Trenching
- Exchequer Dam; gates, butterfly, vertical, and, 777
- Filter Bed; excelsior and, 782, 783
- sand and gravel specifications and, 137
- sand sampler and, 145
- Filter, Experimental; Cincinnati and, 617-18
- Detroit and, 143
- Tampa, Fla., and, 275
- Filtration, Double; London, Eng., and, 149, 775
- Filtration, Pressure; softened water and, 150
- Filtration, Rapid Sand; designs, British, and, 775
- experiments and, 495, 618
- filter bed mechanism and, 495-6
- head loss experiments and, 495
- Tampa, Fla., and; underdrains and, 276
- wash and; water wheel drive and, 498
- see* Filter Bed
- Filtration, Slow Sand; alumina filming and, 271, 614
- tropics and, 271, 614
- Fish; phenols and; tastes and, 404
- Flood; Denver, Colo., and; control and, 139
- flow and; Jarvis formula and, 137
- Los Angeles, Cal., and; control and, 139
- Paris, France, and; control and, 137
- sanitary hazards and, 400
- small stream; data, hydraulic, and, 779
- Flow; calculation and, 140, 146, 626
- forces and, 626
- measurement and, 273, 274, 497
- water hammer and, 626
- see* Flood; Pipe, Flow and; Venturi; Weir
- Fox River, Ill.; conservancy district and, 498
- France; water supply practice and, 495
- wells, artesian, and, 272
- Franzensbad, Czechoslovakia; mineral waters and; iron, active, and, 272
- Gage; pressure or level; electric, new, 614
- Galvanized Iron; Auperle and Bauer reagents and, 624
- wire and; durability and, 781
- zinc coating and; thickness determination and, 624
- Gammarus Pulex*; pollution and; indicator and, 402
- Gases Dissolved; discussion, general, and, 406
- Gate; staunching and; fabric and, 779
- see* Dam
- Germany; ground water and, 405
- pipes and; corrosion and, 273
- Gila River; Coolidge dam and, 143
- Glenshaw, Penn.; typhoid and, 399
- Goiter; drinking water and, 273, 399
- Great Lakes; levels and; sun spots and, 499
- Ground Water; German cities and, 406
- Illinois and, 502-3
- Gunite; dam protection and, 777
- ditch lining and, 619
- Haiti; water supplies, public, and, 500
- Hales Bar, Tenn.; dam and; leakage control and, 140
- Hannibal, Mo.; water supply, additional, and, 270
- Hardness; conductivity and, 269
- figures, high, and, 502
- ground water and; Illinois and, 502-3
- see* Softening
- Hartford, Conn.; compensation water and, 496
- Havelock, Neb.; well system, new, and, 498
- Head; filtration and; experiments and, 495
- gage, electric, and, 614
- Hetch Hetchy; progress and, 135
- Holland; water supply practice and, 495
- Housatonic River; New York City and, 777
- Hudson Bay; drainage data and, 401
- Hydrant; European practice and, 495
- Hydraulics; *see* Books, New
- Hydrodynamics; *see* Books, New
- Hydrogen Electrode; flowing liquids

- and, 405
- Lehmann micro-electrode and, 405
- Hydrogen Ion Concentration; coagulation and, 278
- control and, 277
- tastes, chlorophenol, and, 133
- o*-tolidin test and, 277
- zeolite and, 278, 626
- see* Analysis; Books, New
- Ice; dam protection and, 777
- destruction and; thermit and, 495
- manufacture and; lime and, 402
- Illinois; cities and; water supplies and, 400
- conservancy districts and, 498
- ground water supplies and, 502-3
- Inspection; systematic; power houses and, 617
- Insulation; piping and, 617
- Intake; Bay City, Mich., and, 136
- lakes and; depth and, 143
- wells and, 143
- Marston Lake, Denver, Colo., and, 267-8
- St. Louis, Mo., and; construction and, 142, 267
- Interest; during construction; capital and, 774
- Iodide; chlorination and; tastes and, 133
- Iodine; water and; goiter and, 399
- Iron; water and; activity and, 272
- catalytic capacity and, 272
- light and; oxidation and, 272
- purity and, 401
- wells, coastal, and, 401
- wrought; manufacture and, 784
- Iron, Corrosion and; chromium and, 401-2
- copper and, 401-2, 406
- drops and; carbon dioxide and, 405-6
- endurance and; lowering and, 779
- Europe and, 495
- ferrous carbonate solubility and, 774
- films and; theories and, 403
- losses, annual, and, 613
- manganese and, 401-2
- nickel and, 401-2
- pipes and; Germany and, 273
- pitting and; mechanism and, 774-5
- rust and, 774-5
- silicon and, 401-2
- sodium chloride and, 274
- theories and, 403, 620, 784
- tungsten and, 401-2
- waters, natural, and, 774
- see* Boiler Corrosion; Books, New; Corrosion
- Iron, Galvanized; *see* Galvanized Iron
- Iron, Protection and; blue lead and, 621
- coatings and; characteristics, desirable, and, 613
- lead and, 406
- metals and, 501
- varieties and, 620
- see* Galvanized Iron; Paint
- Italy; water supply practice and, 495
- Java, N. E. I.; filtration, rapid sand, and, 272
- Joukovsky; water hammer formula and, 777
- Kansas City, Mo.; tunnel explosion and, 777
- Lansing, Mich.; water supply and, 141
- Laundry; softening and; economy and, 273
- Law; interest during construction and, 775
- Massachusetts and; legislation, recent, and, 276
- water lien and, 276
- pollution abatement and, 399
- rate structure and, 494
- typhoid and; Albany, N. Y., and, 147
- Owen Sound, Ont., and, 148, 501
- Lead; blue; properties and, 621
- Leamington, Ont.; gravel wall well and, 623
- Level; gage, electric, new, and, 614
- Lime; wastes, textile, and, 403
- water treatment and, 402
- Linseed; boiler scale prevention and, 407
- Liverpool, Eng.; water supply and; aëration and, 776
- enlargement and, 776
- London, Eng.; filtration, double, and, 149, 775
- Los Angeles; flood control and; controversy and, 145
- Owens Valley and; wells and, 619
- water rates, increased, and, 499
- water supply and; Colorado River and, 136
- consumption and, 136
- problems and, 136
- Madison River, Montana; water power and; irrigation and, 493
- Madras, India; water supply and; report, annual, and, 271, 614

- Magnesium Chloride; boiler corrosion and, 273
 Main; Mississippi crossing and, 145
 Manitoba; drainage and; data and, 401
 Marin, Cal.; pipeline and; hillsides and, 272
 Marquette, Mich.; phenol wastes and; intake depth and, 143
 Marston Lake, Colo.; intake and, 267-8
 Massachusetts; legislation, recent, and, 276
 water lien law and, 276
 Mattress; concrete, reinforced, flexible, and, 781
 wire-weave *vs.* basket-weave, 619
 Metal; endurance testing and, 779
 Meter; European practice and, 495
 see Books, New; Venturi
 Miami River, Ohio; conservancy district and; experiments and, 620
 Michigan, Lake; intakes and; depth and, 143
 Mineral Content; discussion, general, and, 406
 high; Illinois and, 502
 Minneapolis; filtration plant, new, and, 138
 transport, pneumatic, and, 138
 Mississippi and; main crossing and, 145
 Mississippi River; Minneapolis and; main and, 145
 Missouri; cement specifications and, 269
 Missouri River; regulation and; Lexington Bridge and, 778
 Moffat Tunnel, Colo.; watercourse and, 268
 Mokelumne River; East Bay project and; pipeline and, 771
 progress and, 135
 Mortar; analysis and, 622
 Motor (electric); direct current; starting and, 614
 Moyie River, Idaho; dam failure and, 775
 Mud Ball; analysis and, 500
 removal and, 268, 500
 Muskogee, Okla.; water supply and, 499

 Nashua River; Boston and, 145
 New Brunswick, Can.; drainage data and, 401
 New England; rainfall and; records and, 276
 New Jersey; summer resorts and, 400
 typhoid and; 1925 and, 400
 New Milford, Penn.; typhoid and, 399
 New York City; Housatonic River and, 777
 Jamaica sewage plant foundations and, 268
 Norfolk and Western R. R.; Roanoke, Va., and; water treating plant and, 783
 North Carolina; stream flow records and, 493
 Nova Scotia, Can.; drainage data and, 401

 Oil; boiler feed water and; removal and, 624, 774
 Oil, Fuel; coal and; cost comparison and, 141
 Oklahoma City, Okla.; mud ball removal and, 500
 Omaha, Neb.; water supply and, 498
 Ontario, Can.; drainage data and, 401
 Owen Sound, Ont.; typhoid and; liability and, 148, 501
 Owens River; Los Angeles and; wells and, 619
 Oxygen Dissolved; boiler feed water and; recorder and, 406

 Pacific Gas and Electric Co.; Pit No. 3 plant and, 137
 Pacoima; dam and, 145
 Paint; humidity and; drying and, 621
 rust preventing; alkali and, 620
 bituminous, 622
 iron oxide and, 622
 lead chromate and, 622
 permeability and, 620
 specifications and, 622
 tests, rapid, and, 270, 621
 varnish and, 622
 zinc oxide and, 622
 steel and; steam *vs.* air drying and, 406
 sunlight and; cracking and, 621
 surface, clean, and; necessity and, 622
 water line; comparisons and, 622
 Palm Beach, Fla.; pumping plant and; foundations and, 499
 Paper Manufacture; water supply and, 147
 Paris, France; flood protection plans and, 137
 Pennsylvania; typhoid and; out-breaks, recent, and, 399
 Pennsylvania R. R.; steel and; corrosion tests and, 406
 paint tests and, 406
 Penstock; steel to concrete junction and, 137

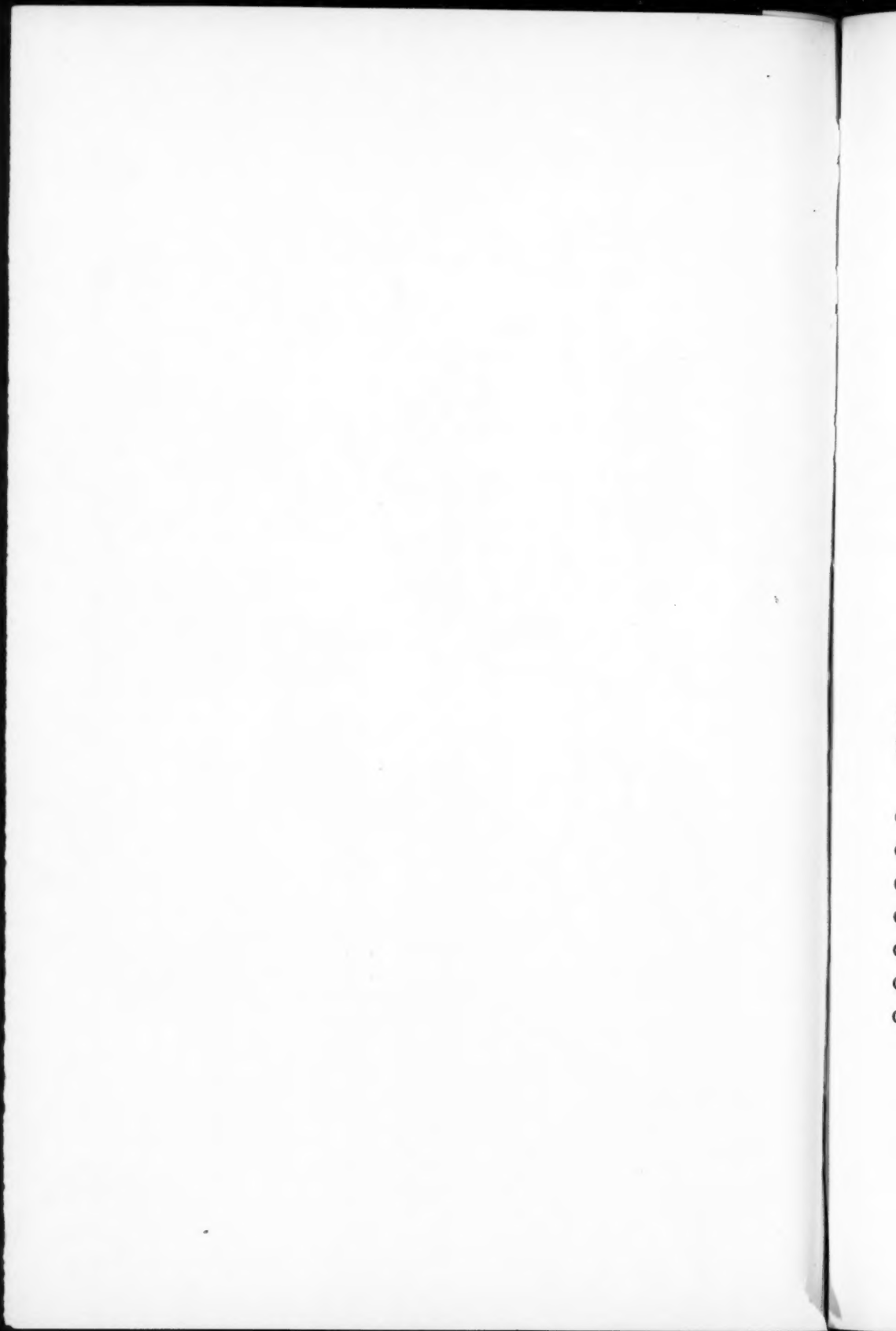
- Pequannock River, N. J.; dam, old, and, 138
- Phenol; chlorination and; tastes and, 133-4
removal and, 133-4
fish and, 404
removal and; benzene and, 404
flue gas and, 405
oxidation, biological, and, 404
tastes and, 404
- Pile; concrete; St. Louis intake and, 267
- Pipe; calculations and, 626
drilling and, 136
European practice and, 495
hangers and, 617
insulation and, 617
intersections and; energy losses and, 772, 779
power plant draft tube; cast iron lining and, 781
see Corrosion
- Pipe, Cast Iron; advantages and, 496
Europe and, 495
France and, 495
- Pipe, Cement-Asbestos; Italy and, 495
- Pipe, Cement-Lined; European practice and, 495
- Pipe Coating; Mokelumne project and, 771
see Pipe, Steel
- Pipe, Concrete; under sea; laying and, 781
see Pipe Joint
- Pipe, Flow and; bibliography and, 626-7
calculations and, 626, 627
concrete; age and, 136
formula and, 136
intersections and, 772, 779
water hammer and, 626
see Flow
- Pipe Joint; concrete; under sea, 781
European practice and, 495
flexible; tightness and, 778
pipe, concrete, and, 136, 781
- Pipe, Steel; coating and, 141, 771
economy and; San Francisco and, 141
electrolysis and, 141
history and, 141
lockbar; leakage and; Detroit and, 781
Mokelumne project and, 771
welding, electric, and, 771
- Pipeline; air inlet valves and, 780
Athens, Greece, and, 620
concrete; Denver, Colo., and, 136
flow and, 136
Seattle, Wash., and, 135
hillside and; laying and, 272
Mokelumne project and, 771
pressure, external, and, 780
St. François River and; current, swift, and, 621
steel; Mississippi river crossing and, 145
Seattle water supply and, 135
submarine; laying and, 271, 778
leakage, low, and, 146
see Penstock
- Pitting; *see* Boiler Corrosion
- Pollution; abatement and; enforcement and, 399
bacteriophage and, 502
indicators, living, and, 402
summer hotels and, 400
- Port Angeles, Wash.; reservoir and; lining, concrete, and, 142
water supply and, 142
- Potentiometer; design, special, and, 405
- Power; *see* Books, New
- Power House; piping and; insulation and, 617
lay-out and, 617
- Power Station; *see* Inspection
- Preheat; pump and, 149
see Boiler Feed Water
- Pressure; gage, electric, new, and, 614
- Priming; *see* Boiler, etc.
- Prince Edward Island, Can.; drainage data and, 401
- Providence, R. I.; compensation water and, 496
- Pump, Air Lift; advantages and; Lansing, Mich., and, 141
- Pump, Centrifugal; side suction and, 614
specifications and; exactitude and, 496
- Pumping Plant; Banta-Carbona, Cal.; irrigation and, 772
Buffalo, N. Y., and, 147
control, automatic, and, 772
costs, operating, comparative, and, 140
- St. Paul, Minn., and; efficiency and, 144
- Western Avenue, Chicago, and; design and, 140
- Purification; efficiency demands and, 500
progress and, 774
- Quicksand; concrete placing and; control and, 146
- Quinapoxet River; water supply and; Worcester, Mass., and, 145

- Radioactivity; Algeria and, 403
Chaudfontaine, Belgium, and, 404
- Railroad; drinking water regulations and, 784
water treatment and, 624-5, 783, 784
- Rainfall; New England and; records and, 276
- Rate; Los Angeles and, 499
structure and; principles and, 494, 785-6
- Red Water; control and; lime and, 402
- Reservoir; Athens, Greece, and, 620
compensating; diversions and, 496
Oneida, N. Y., and, 773
Port Angeles, Wash., and, 142
Queen Mary, England, 495
San Diego, Cal.; recreational use and, 270
South Pasadena and; failure and, 771
rebuilding and, 771
- Retard; Fountain River, Colo., and, 776
Missouri River and, 778
- Rhode Island; water supplies and; statistics and, 275
- Richmond, Va.; sprinkler installation and, 400
- River; *see* Stream
- Rivet; steel and; sulfur and, 620
- Roanoke, Va.; N. & W. R. R. water treating plant and, 783
- Rockford, Ill.; well, deep, and, 502
- Rotameter; flow measurement and, 273
- Ruhr, Germany; sewage problems and, 404
tastes and, 404
- Run-off; snow surveys and, 619
- Sacramento River; bank protection and, 772
- St. Catharine's, Ont.; water supply, new, and, 775
- St. François River, Que.; current, swift and; main laying and, 621
- St. Lawrence River; drainage data and, 401
- St. Louis; intake, new; construction and, 142, 267
mud ball removal and, 268
- St. Paul, Minn.; pumping plant, new, and, 144
- St. Petersburg, Fla.; water hyacinth and, 497
- Salt River, Arizona; irrigation project and, 143
ditches and; lining and, 619
Mormon Flat dam and, 138
water power developments and, 139
- San Diego, Cal.; reservoir and; recreational use and, 270
- San Francisco; area, metropolitan, and; earthquake hazards and, 266
water supplies, prospective, and, 266
pipe, riveted, and, 141
pipeline, submarine, and; leakage, small, and, 146
see Hetch Hetchy
- San Gabriel River; dam and; world record and, 145
water level contours and, 493
- Sand; filter; specifications and, 495
wet; foundations and, 268, 499
see Filter Bed; Quicksand
- Saskatchewan, Can.; drainage data and, 401
- Scour; Alamo Canal and, 771
- Sea Water; fresh water and; mixing and, 782
see Books, New
- Seattle, Wash.; ship canal and; sea water exclusion and, 781
L. Youngs development and, 135
- Service Pipe; European practice and, 495
- Sherbrooke, Que.; St. François River and; main and, 621
- Sierra Nevada; snow surveys and; run-off and, 619
- Snow; surveys and; run-off and, 619
- Sodium Acetate; boiler water and, 277
- Sodium Carbonate; boilers and; hydrolysis and, 277
- Sodium Chloride; corrosion and, 274
priming and, 277
see Boiler Water
- Sodium Formate; boiler water and, 277
- Sodium Silicate; corrosion prevention and, 403
stone, artificial, and; protection and, 621
- Sodium Sulfate; boiler water and, 277
- Softening; Britain and, 402
calculations and; charts and, 148
cost and; Columbus, Ohio, and, 139, 499
hydrogen-ion concentration and, 278
split- and over- treatment and, 498-9
see Boiler Feed Water; Laundry; Zeolite
- South Pasadena, Cal.; reservoir and, 771
- Southern Pacific R. R.; zeolite treatment and, 783

- Spillway; Alouette, B. C., dam and, 138
 scour and; control and, 144
 Taintor gates and, 139
 Spontaneous Combustion; *see* Coal
 Spring; activity and, 272
 Sprinkler; advantages and, 400
 wet *vs.* dry pipe systems and, 400
 Squillehuck Creek, Wash.; flood and; data, hydraulic, and, 779
 Steel; endurance and; corrosion and, 779
 fatigue and, 779
 Steel, Rustless; developments, modern, and, 403
 Krupp V₂A and, 402
 Stone; artificial; protection and; sodium silicate and, 621
 Stream; activity and, 272
 control and; calculations and, 782
 storage and, 782
 surveys (river); index and, 493
 Sulfur; concrete treatment and, 267
 Sulfur Dioxide; de-chlorination and, 134
 de-colorization and, 275
 generation and, 275
 Sulfuretted Hydrogen; Madras, India, and, 271, 614
 Sunspot; Great Lakes levels and, 499
 Super-chlorination; *see* Chlorination
 Superheat; scale trouble and, 406-7
 Surface Water; activity and, 272
 Swift River; Boston and, 145
 Swimming Pool; chlorination and; uniformity and, 147
 operation and, 403
 Taintor Gates; Mormon Flat dam and, 139
 Tampa, Fla.; carbonation and, 275-6
 color removal and, 275
 filter, experimental, and, 275
 underdrains and, 276
 water supply, new, and, 275
 Tank; steel, large; Charleston, S. C., and, 141-2
 Taste; algae and, 499
 creosote and; prevention and, 622
 taste-index and, 622
see Chlorination
 Temperature; wells, deep, and, 147
 Tennessee River; Hales Bar dam and, 140
 Textile; wastes and; treatment and, 403
 water supply and, 273
 Thermit; ice destruction and, 495
 Tientsin, China; well supply and, 613
 Titration; dropping bottle, calibrated, and, 274
 o-Tolidin; chlorine test and; H-ion concentration and, 277
 sunlight and, 135
 Tölz; *see* Books, New
 Topeka, Kansas; water supply, new, and, 138
 Torch; electric; under water cuts and, 613
 illuminating gas; economy and, 618
 Toronto, Ont.; chlorination and; tastes and, 133-4
 Trenching; pipeline and; cost and, 777
 Trinity River; Dallas, Texas, and; flood protection and, 619
 Tropics; sulfuretted hydrogen troubles and, 271, 614
 Tryon, N. C.; dam failure and, 775
 Tunnel; blast, under water, and, 772
 Kansas City and; explosion and, 777
 Moffat; water encountered and, 268
 mucking and; air lift and, 268
 New Cascade; Great Northern R. R. and, 500
 Seattle; water supply and, 135
 Turbidity; Colorado River and, 146
 lakes and; undertow and, 143
 waves and, 143
 turbidimeter, Baylis, and; sensitivity and, 501
 turbidimeter, portable, and, 776
 Turbine, Steam; *see* Books, New
 Turbine, Water; runner replacement and, 138
 Typhoid; Albany, N. Y., and; litigation and, 147
 East Liverpool and; reduction and, 780
 floods and, 400
 New Jersey and; 1925 and, 400
 Owen Sound, Ont., and; liability and, 148
 Pennsylvania and; outbreaks, recent, and, 399
 Underdrain; *see* Filtration, Rapid Sand
 Utility; rates and, 785-6
see Books, New
 Valuation; principles, equitable, and, 494
 water power and, 778
 Valve; boxes, roadway, and; concrete, and, 621
 design and, 497
 operation and; motors and, 497
 pressures, extreme, and, 398
 Vancouver, B. C.; pipeline, submarine, and, 271

- Venice, Neb.; connections and meters and; rules and, 779
- Venturi Meter; accuracy and; experiments and, 782
discharge coefficients and, 782
flow measurement and, 782
- Vienna, Austria; water supply and; hydrology and, 501
- Ware River; Boston and, 145
- Wash; *see* Filtration, Rapid Sand
- Washington, D. C.; aqueduct repairs and, 148
- Waste, Industrial; coal distillation, vertical, and, 405
dairy; treatment and, 623
textile; treatment and, 403
- Water, Bottled; imports and; classification and, 775
- Water Hammer; head and; variation and, 777
Joukovsky formula and, 777
see Books, New
- Water Hyacinth; removal and, 497
- Water Power; Canada and, 401
Czechoslovakia and, 613-4
valuation and, 778
- Water Supply; improvement and; trend and, 497
see Books, New
- Water Works; administration and, 785
England and, 495
France and, 495
statistics and; tabulation and, 148
see Books, New
- Weir; flow measurement and, 143, 782
- Weld; acetylene; experiences and, 773
electric; economy and, 403-4
Mokelumne pipeline and, 772, 773
stresses developed and, 773
tar removal and, 779
see Torch
- Well; artesian; Belgium and France and, 272
temperature and, 147
coastal; iron and carbon dioxide and, 401
deep; Illinois and, 502
gravel wall and; Leamington, Ont., and, 623
Tientsin, China, and, 613
water level and; measurement and, 147
see Books, New
- West Palm Beach, Fla.; pumping plant and; foundations and, 499
- Winsted, Conn.; water supply pollution and, 399
- Worcester, Mass.; water supply and; Boston and, 145
- L. Youngs; Seattle, Wash., and, 135
- Yukon, Can.; drainage data and, 401
- Zeolite; artificial; bentonite and, 404
hydrogen-ion concentration and, 278, 626
softening and, 276, 783
see Boiler Feed Water; Softening

ADVERTISEMENT SECTION



CLASSIFIED INDEX TO ADVERTISEMENTS

	PAGE		PAGE
Air Compressors:		Chemicals for Laboratory Use:	
Allis-Chalmers Mfg. Co.....	60	Digestive Ferments Co.....	43
Chicago Pneumatic Tool Co....	11	Chemicals for Water Purification:	
DeLaval Steam Turbine Co....	49	Diamond Alkali Co.....	40
Sullivan Machinery Co.....	64	General Chemical Co.....	22
Worthington Pump & Mach.		International Salt Co.....	50
Corp.....	31	Mathieson Alkali Works, Inc..	47
Air Lift Pumping Systems:		Pennsylvania Salt Mfg. Co.....	
Chicago Pneumatic Tool Co....	11	Isaac Winkler & Bro.....	48
Sullivan Machinery Co.....	64	Chemists and Engineers:	
Alum:		(See Directory of Experts, page 13)	
General Chemical Co.....	22	Chlorinators:	
Pennsylvania Salt Mfg. Co....		Paradon Manufacturing Co....	59
Isaac Winkler & Bro.....	48	Wallace & Tiernan Co., Inc.	
Brass Goods:			Cover 3
(See also Pipe, Brass)		Chlorine, Liquid:	
American Brass Co.....		Arnold, Hoffman & Co., Inc...	39
Copper & Brass Research Ass'n.		Mathieson Alkali Works, Inc..	47
Farnan Brass Co.....	58	Pennsylvania Salt Mfg. Co.....	
Glauber Brass Mfg. Co.....	36	Wallace & Tiernan Co., Inc.	
Kennedy Valve Mfg. Co.....	26		Cover 3
Mueller Company.....	63	Clarifiers:	
A. P. Smith Mfg. Co.....	37	Dorr Company.....	53
Union Water Meter Co.....	41	Clay Spaders:	
Brass Goods, Lead Lined:		Chicago Pneumatic Tool Co....	11
Cement Lined Pipe Co.....	27	Sullivan Machinery Co.....	64
Brass Well Screens:		Cleaning Water Mains:	
A. D. Cook, Inc.....		General Pipe Cleaning Co.....	50
Edward E. Johnson, Inc.....	18	National Water Main Cleaning	
Calking Hammers, Pneumatic:		Co.....	22
Chicago Pneumatic Tool Co....	11	Cocks, Curb and Corporation:	
Calking Tools:		Glauber Brass Mfg. Co.....	36
Mueller Company.....	63	Farnan Brass Co.....	58
Cast Iron Pipe:		Mueller Company.....	63
(See Pipe)		A. P. Smith Mfg. Co.....	37
Caustic Soda:		Union Water Meter Co.....	41
(See Soda, Caustic)		Concrete Breakers (Pneumatic):	
Cement Lined Pipe:		Chicago Pneumatic Tool Co....	11
(See Pipe)		Sullivan Machinery Co.....	64
Cement Lining Presses:		Condensers:	
Union Water Meter Co.....	41	Allis-Chalmers Mfg. Co.....	60
Chemical Feed Apparatus:		Chicago Pneumatic Tool Co....	11
American Water Softener Co..	32	Copper & Brass Research Ass'n.	
Dorr Company.....	53	U. S. Cast Iron Pipe & Fdy. Co. 9, 23	
F. B. Leopold.....	14	Worthington Pump & Mach.	
Permutit Company.....	56	Corp.....	31
Ross Valve Mfg. Co.....	40	Contracting Engineers:	
W. J. Savage Co., Inc.....	43	Ambursen Construction Co....	13
Simplex Valve & Meter Co....	29	Pitt Construction Co.....	
Wallace & Tiernan Co., Inc.		Copper Sheets:	
	Cover 3	American Brass Co.....	19
		Copper Sulphate:	
		Copper & Brass Research Ass'n.	

	PAGE		PAGE
Couplings, Flexible:		Gages, Surface, Reservoir &	
DeLaval Steam Turbine Co....	49	Special Water Works:	
Couplings for Copper, Iron & Lead		American Water Softener Co..	32
Pipe:		Builders Iron Foundry.....	33
Glauber Brass Mfg. Co.....	36	H. W. Clark Co.....	35
Curb Boxes:		Simplex Valve & Meter Co....	29
H. W. Clark Co.....	35	Gates, Shear and Sluice:	
Glauber Brass Mfg. Co.....	36	Ludlow Valve Mfg. Co.....	28
Mueller Company.....	63	Gate Valves:	
W. P. Taylor Co.....	52	(See Valves)	
Dams:		Gears, Speed Reducing:	
Ambursen Construction Co....	13	DeLaval Steam Turbine Co... 49	
Diaphragms, Pump:		Holsts, Pneumatic:	
Edson Mfg. Corp.....	39	Chicago Pneumatic Tool Co....	11
Drills, Rock:		Holsts, Portable (Air and Electric):	
Chicago Pneumatic Tool Co... 11		Sullivan Machinery Co.....	64
Sullivan Machinery Co.....	64	Hose, Suction & Conduction:	
Engineers and Chemists:		Edson Mfg. Corp.....	39
(See Directory of Experts,		Hydrants, Fire:	
page 13)		A. D. Cook, Inc.....	52
Engines:		Kennedy Valve Mfg. Co.....	26
(See Pumps and Pumping En-		Ludlow Valve Mfg. Co.....	28
gines)		Rensselaer Valve Co.....	45
Feed Water Filters:		Ross Valve Mfg. Co.....	40
Ross Valve Mfg. Co.....	40	A. P. Smith Mfg. Co.....	37
Feed Water Heaters:		R. D. Wood & Co.....	cover 2
Biggs Boiler Works Co.....	21	Hydrants, Sprinkling & Flushing:	
Worthington Pump & Mach.		Ludlow Valve Mfg. Co.....	28
Corp.....	31	Mueller Company.....	63
Filter Rate Controllers and Gages:		Rensselaer Valve Co.....	45
(See Rate Controllers)		A. P. Smith Mfg. Co.....	37
Filters and Water Softening Plants:		R. D. Wood & Co.....	cover 2
American Water Softener Co..	32	Hydrogen Ion Equipment:	
Dorr Company.....	53	LaMotte Chemical Products Co. 24	
Hazen & Whipple.....	14	Inspection of Materials:	
F. B. Leopold.....	14	Conard & Buzby.....	13
Permutit Company.....	56	Investments:	
Filtration Plant Equipment:		(See Securities, Water Com-	
American Water Softener Co... 32		pany)	
Digestive Ferments Co.....	43	Iron Removal Plants:	
F. B. Leopold.....	14	American Water Softener Co.. 32	
Paradon Manufacturing Co....	59	Jointing Materials:	
Permutit Company.....	56	Hydraulic Development Co...	
Simplex Valve & Meter Co....	29	Leadite Company, Inc....	cover 4
R. D. Wood & Co.....	cover 2	Mueller Company.....	63
Fittings, Copper Pipe:		Laboratory Apparatus:	
Glauber Brass Mfg. Co.....	36	Digestive Ferments Co.....	43
Flexible Joints:		Leak Finders:	
John Fox & Co.....	58	H. W. Clark Co.....	35
Glauber Brass Mfg. Co.....	36	Liquid Chlorine:	
U. S. Cast Iron Pipe & Fdy.		(See Chlorine, Liquid)	
Co.....	9, 23	Machines, Drilling:	
R. D. Wood & Co.....	cover 2	Mueller Company.....	63
Flumes, Steel:		Machines, Lead Flanging:	
Biggs Boiler Works Co.....	21	Mueller Company.....	63
Furnaces:			
Mueller Company.....	63		
A. P. Smith Mfg. Co.....	37		

	PAGE		PAGE
Manhole Frames & Covers:		Oil Engines:	
John Fox & Co.....	16	Allis-Chalmers Mfg. Co.....	60
W. P. Taylor Co.....	52	Chicago Pneumatic Tool Co....	11
Meters:		Worthington Pump & Mach.	
Badger Meter Mfg. Co.....	54	Corp.....	31
Buffalo Meter Co.....	42	Packing, Rawhide:	
Builders Iron Foundry.....	33	Mabbs Hydraulic Packing Co..	40
Gamon Meter Co.....	10	Penstocks, Steel:	
Hersey Mfg. Co.....	51	Biggs Boiler Works Co.....	21
National Meter Co.....	44	Pipe, Brass:	
Pittsburgh Equitable Meter Co.	61	American Brass Co.....	
Simplex Valve & Meter Co....	29	Copper & Brass Research Ass'n.	
Thomson Meter Co.....	30	Farnan Brass Co.....	58
Union Water Meter Co.....	41	Kennedy Valve Mfg. Co.....	26
Worthington Pump & Mach.		A. P. Smith Mfg. Co.....	37
Corp.....	31	Pipe, Cast Iron (and Fittings):	
Meters (Venturi Type):		American Cast Iron Pipe Co... 57	
Builders Iron Foundry.....	33	Builders Iron Foundry.....	33
National Meter Co.....	44	Central Foundry Co.....	25
Simplex Valve & Meter Co....	29	John Fox & Co.....	16
Meter Boxes:		McWane Cast Iron Pipe Co... 19	
Builders Iron Foundry.....	33	National Cast Iron Pipe Co... 39	
H. W. Clark Co.....	35	U. S. Cast Iron Pipe & Fdy.	
Pittsburgh Equitable Meter Co.	61	Co.....	9, 23
W. P. Taylor Co.....		Warren Fdy. & Pipe Co.....	18
Meter Couplings:		R. D. Wood & Co.....	cover 2
Badger Meter Mfg. Co.....	54	Pipe, Cement Lined:	
Buffalo Meter Co.....	42	American Cast Iron Pipe Co.. 57	
H. W. Clark Co.....	20	Biggs Boiler Works Co.....	21
Farnan Brass Co.....	58	Builders Iron Foundry.....	33
Gamon Meter Co.....	10	Cement Lined Pipe Co.....	27
Glauber Brass Mfg. Co.....	36	John Fox & Co.....	16
Hersey Mfg. Co.....	51	National Cast Iron Pipe Co... 39	
Mueller Company.....	63	U. S. Cast Iron Pipe & Fdy.	
National Meter Co.....	44	Co.....	9, 23
Pittsburgh Equitable Meter Co.	61	Warren Fdy. & Pipe Co.....	18
Thomson Meter Co.....	30	R. D. Wood & Co.....	cover 2
Union Water Meter Co.....	41	Pipe, Concrete:	
Meter Coupling Yokes:		Lock Joint Pipe Co.....	
H. W. Clark Co.....	35	Pipe, Copper:	
Meter Reading and Record Books:		Copper & Brass Research Ass'n.	53
Buffalo Meter Co.....	42	Mueller Company.....	33
Meter Testers:		Pipe Cutting Machines:	
Badger Meter Mfg. Co.....	54	A. P. Smith Mfg. Co.....	37
Buffalo Meter Co.....	42	Pipe Jointing Materials:	
Builders Iron Foundry.....	33	(See Jointing Materials)	
H. W. Clark Co.....	35	Pipe, Lead Lined (and Fittings):	
Hersey Mfg. Co.....	51	Biggs Boiler Works Co.....	21
Mueller Company.....	63	Cement Lined Pipe Co.....	27
National Meter Co.....	44	Pipe Locators:	
Pittsburgh Equitable Meter Co.	61	H. W. Clark Co.....	20
Meter Washers:		Pipe, Pressure, Riveted and	
Mabbs Hydraulic Packing Co..	40	Welded:	
Motors, Electric:		Biggs Boiler Works Co.....	21
Allis-Chalmers Mfg. Co.....	60	Penstock Construction Co....	16
		Pipe, Steel:	
		Biggs Boiler Works Co.....	21
		East Jersey Pipe Co.....	38

	PAGE		PAGE
Pipe, Tin Lined:		Stacks:	
Biggs Boiler Works Co.....	21	Biggs Boiler Works Co.....	21
Pipe, Wrought Iron:		Penstock Construction Co.....	48
A. M. Byers Co.....		Steel Plate Construction:	
Pressure Regulators:		Biggs Boiler Works Co.....	21
Golden-Anderson Valve Spec.		Sulphate of Alumina:	
Co.....	20	(See Alum)	
Mueller Company.....	63	Tanks, Mixing:	
Ross Valve Mfg. Co.....	40	Dorr Company.....	53
Simplex Valve & Meter Co.....	29	Tanks, Steel:	
Union Water Meter Co.....	41	Biggs Boiler Works Co.....	21
Provers, Water:		Penstock Construction Co.....	48
Pittsburgh Equitable Meter Co.	61	W. J. Savage Co., Inc.....	43
Pumps, Deep Well:		Tapping Machines:	
A. D. Cook, Inc.....		Glauber Brass Mfg. Co.....	36
Worthington Pump & Mach.		Mueller Company.....	63
Corp.....	31	A. P. Smith Mfg. Co.....	37
Pumps, Diaphragm (Hand &		Tapping Sleeves:	
Power):		(See Sleeves & Valves, Tapping)	
Edson Mfg. Corp.....	39	Tires, Fire Engine & Truck (Pneu-	
Pumps & Pumping Engines:		matic):	
Allis-Chalmers Mfg. Co.....	60	Firestone Tire & Rubber Co....	17
A. D. Cook, Inc.....		Turbines, Steam:	
DeLaval Steam Turbine Co....	49	Allis-Chalmers Mfg. Co.....	60
Edson Mfg. Corp.....	39	DeLaval Steam Turbine Co....	49
F. B. Leopold.....	14	Turbines, Water:	
Ross Valve Mfg. Co.....	40	DeLaval Steam Turbine Co....	49
Sterling Engine Co.....	48	Valve Boxes:	
Worthington Pump & Mach.		H. W. Clark Co.....	35
Corp.....	31	John Fox & Co.....	58
Rate Controllers:		Kennedy Valve Mfg. Co.....	26
American Water Softener Co..	32	Ludlow Valve Mfg. Co.....	28
Builders Iron Foundry.....	33	Mueller Company.....	50
F. B. Leopold.....	14	Rensselaer Valve Co.....	45
Simplex Valve & Meter Co....	29	A. P. Smith Mfg. Co.....	37
Securities, Water Company:		R. D. Wood & Co.....	cover 2
P. W. Chapman & Co.....	12	Valve Inserting Machines:	
Service Clamps, Galvanized:		A. P. Smith Mfg. Co.....	37
Glauber Brass Mfg. Co.....	36	Valves, Check, Flap, Foot, Hose,	
Mueller Company.....	63	Mud & Plug:	
Shovels, Underground:		Ludlow Valve Mfg. Co.....	28
Allis-Chalmers Mfg. Co.....	60	Valves, Compounding:	
Sleeves & Valves, Tapping:		Union Water Meter Co.....	41
Ludlow Valve Mfg. Co.....	28	Valves, Gate:	
Mueller Company.....	63	A. D. Cook, Inc.....	59
Rensselaer Valve Co.....	45	Farnan Brass Works.....	58
A. P. Smith Mfg. Co.....	37	Glauber Brass Mfg. Co.....	36
R. D. Wood & Co.....	cover 2	Kennedy Valve Mfg. Co.....	26
Soda Ash:		Ludlow Valve Mfg. Co.....	28
Arnold, Hoffman & Co.....	39	Mueller Company.....	63
Diamond Alkali Co.....	40	Rensselaer Valve Co.....	45
Mathieson Alkali Works, Inc..	47	A. P. Smith Mfg. Co.....	37
Isaac Winkler & Bro.....	48	U. S. Cast Iron Pipe & Fdy.	
Soda, Caustic:		Co.....	23
Arnold, Hoffman & Co.....	39		
Diamond Alkali Co.....	40		

	PAGE		PAGE
Valves, Gate (Continued):		Water Cranes:	
R. D. Wood & Co.....	cover 2	Ludlow Valve Mfg. Co.....	28
Worthington Pump & Mach.		Water Waste Detection:	
Corp.....	31	Simplex Valve & Meter Co.....	29
Valves, Regulating:		Well Screens:	
Golden-Anderson Valve Spec.		A. D. Cook, Inc.....	
Co.....	20	Edward E. Johnson, Inc.....	18
Mueller Company.....	63	Well Supplies:	
Ross Valve Mfg. Co.....	40	A. D. Cook, Inc.....	
Union Water Meter Co.....	41	Wrought Iron Pipe:	
		(See Pipe)	

ALPHABETICAL LIST OF ADVERTISERS

	PAGE		PAGE
Allis-Chalmers Mfg. Co.....	60	La Motte Chemical Co.....	24
Alvord, Burdick & Howson.....	13	Leadite Company, Inc., The. cover	4
Ambursen Construction Co.....	13	Lee, Charles H.....	14
American Cast Iron Pipe Co.....	57	Leopold, F. B.....	14
American Public Health Asso.....	46	Lock Joint Pipe Co.....	
American Water Softener Co.....	32	Ludlow Valve Manufacturing	
Arnold Hoffman & Co.....	39	Company, The.....	28
Badger Meter Co.....	54	Mabbs Hydraulic Pkg. Co.....	40
Belle Alkali Co.....	39	Mathieson Alkali Works.....	47
Biggs Boiler Works Co.....	21	McWane Cast Iron Pipe Co.....	19
Black and Veatch.....	13	Metcalf and Eddy.....	14
Blaisdell, Hiram W.....	13	Mueller Company.....	63
Buffalo Meter Company.....	42	Mullergren, Arthur L.....	14
Builders Iron Foundry Co.....	33	National Cast Iron Pipe Company.	39
Burns & McDonnell Engineering		National Meter Company.....	44
Co.....	13	National Water Main Cleaning	
Caird, James M.....	13	Company.....	22
Cement Lined Pipe Co.....	27	Neptune Meters Co.....	55
Central Foundry Co.....	25	Paradon Manufacturing Co.....	59
Chapman & Co., P. W., Inc.....	12	Pearse, Greeley & Hansen.....	14
Chester, J. N., Engineers.....	13	Penstock Construction Co.....	48
Chicago Pneumatic Tool Co.....	11	Permutit Company.....	56
Clark, H. W., Co.....	35	Pitometer Co.....	14
H. Burdette Cleveland.....	13	Pittsburgh Equitable Meter Com-	
Cole, Edward S.....	13	pany.....	61
Conard and Buzby.....	13	Potter, Alexander.....	15
DeLaval Steam Turbine Co.....	49	Potts, Clyde.....	15
Diamond Alkali Co.....	40	Rensselaer Valve Co.....	45
Digestive Ferments Co.....	43	Ross Valve Manufacturing Com-	
Dorr Company.....	53	pany.....	40
East Jersey Pipe Co.....	38	Sanborn & Bogert.....	15
Edson Manufacturing Corp.....	39	Savage, W. J., Co., Inc.....	43
Farnan Brass Works.....	58	Scofield Engineering Co.....	15
Firestone Tire & Rubber Co.....	17	Simplex Valve and Meter Co.....	29
Fox, John & Co.....	58	Smith, A. P., Manufacturing Co..	37
Fuller and McClintock.....	14	Sterling Engine Co.....	48
Gamon Meter Company.....	10	Sullivan Machinery Co.....	64
Ganz, Albert F., Inc.....	14	Thomson Meter Company.....	30
General Chemical Company.....	22	Union Water Meter Company....	41
General Pipe Cleaning Co.....	50	United States Cast Iron Pipe and	
Glauber Brass Mfg. Co.....	36	Foundry Company.....	9, 23
Golden-Anderson Valve Specialty		Van Cleve Laboratories Co.....	15
Company.....	20	Vermeule & Cleveland.....	15
Gordon, F. G.....	14	Wallace & Tiernan Co., Inc. Cover	3
Hazen & Whipple.....	14	Wanted	
Hersey Manufacturing Company.	51	Positions.....	16, 58
Hill, Nicholas S., Jr.....	14	Warren Foundry and Pipe Com-	
International Salt Co.....	50	pany.....	18
Johnson, Edward E.....	18	Weston and Sampson.....	15
Kennedy Valve Mfg. Co.....	26	White & Co., Gilbert C.....	15
Kirchoffer, William Gray.....	14	Wiggin, Thos. H.....	15
		Winkler, Isaac & Bro.....	48
		Wood, R. D. & Co.....	cover 2
		Worthington Pump and Machin-	
		ery Corp.....	31

PHOTOGRAPH
showing part
of a cast iron pipe
installation at
Chicago, Illinois.



Standard Bell and Spigot
can be laid easily - - -
even under the most unusual conditions

THE cast iron pipe illustrated here passes
through an *unlined* rock tunnel.

The strength of Cast Iron Pipe makes this
type of installation possible. The accessi-
bility of lines laid in this manner will be
quickly appreciated by engineers.

Contractors have long been aware of the ease
of standard Cast Iron Pipe installations and
can make their bids accordingly.

*We maintain a special Service Department for the
assistance of contractors and construction engineers.
Information about it will be sent to you gladly—
write for details, there is no obligation involved.*

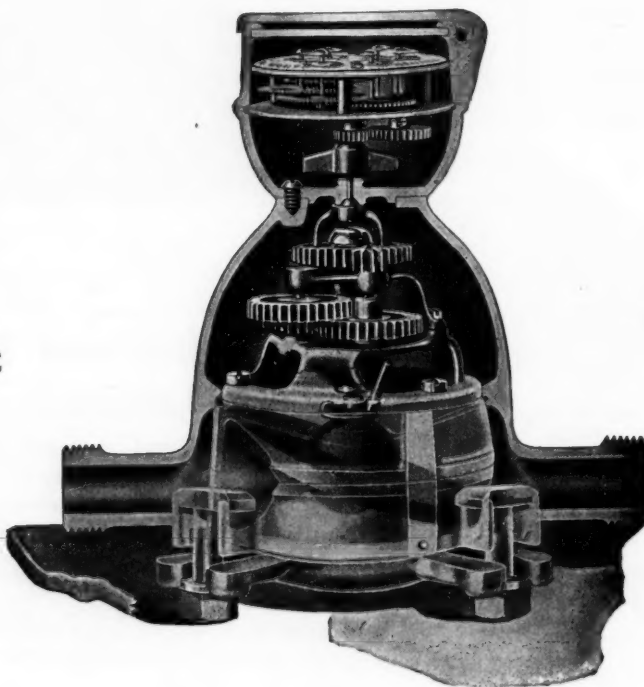
United States Cast Iron Pipe and Foundry Company

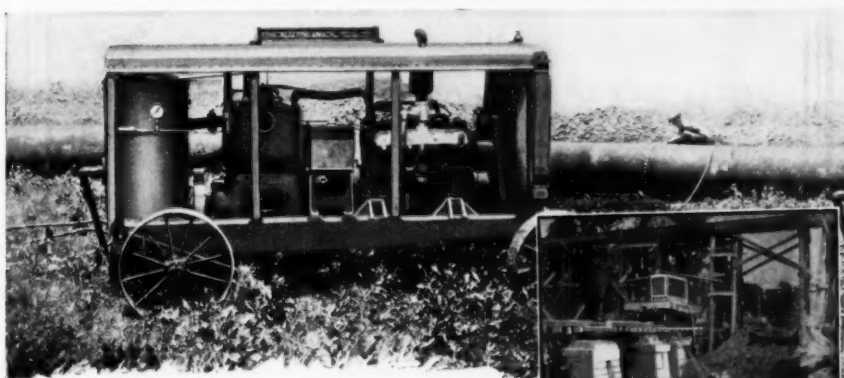
SALES OFFICES

Philadelphia	New York
Chicago	San Francisco
Birmingham	Pittsburgh
Buffalo	Dallas
Cleveland	Kansas City
Minneapolis	

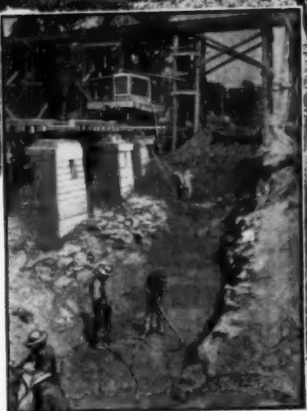
General Offices:

Burlington, New Jersey

**"WATCH DOG" WATER METERS****ACCURATE****DURABLE****DISC, CURRENT AND COMPOUND TYPES***Inquiries Solicited***GAMON METER COMPANY****NEWARK****NEW JERSEY**



CP Equipment on the Spavinaw Water Project



TULSA'S new \$7,000,000 water-supply project for carrying water to the city from the Ozark Mountains, sixty miles away, has been pushed through to a successful completion.

In overcoming difficult construction problems and adverse drilling conditions, Chicago Pneumatic equipment has played a principal part.

The CP Portable Compressor shown above is supplying air for the Boyer Calking Hammer used to calk the 30-inch Boyer riveted main leading from the Mohawk Pump Station to the City of Tulsa.

The inside bucking was done with a CP No. 5 Combination Holder-On.

The lower illustration shows one of the two CP Compressors mounted on flat cars for supplying air at one end of the Grand River crossing.

Other Chicago Pneumatic equipment used on this project included 26 CP-10, several CP-8 and CP-5 rock drills, as well as CP hose couplings, hose and drill steel, Boyer Riveting Hammers, Staybolt-Riveters and Red GIANT Reamers.

Let us send you full information on the CP equipment best suited to your needs.

J-216-S



Chicago Pneumatic Tool Co.

Sales and Service Branches All Over the World

6 East 44th Street

NEW YORK, N. Y.



Underwriters
and
Distributors

of

WATER COMPANY
SECURITIES

We invite inquiry



P.W. CHAPMAN & CO., INC.

42 Cedar Street
NEW YORK

116 So. La Salle Street
CHICAGO

DIRECTORY OF EXPERTS

ALVORD, BURDICK & HOWSON

J. W. Alvord—C. B. Burdick—L. R. Howson

ENGINEERS FOR

Water Works	Sewage Disposal
Water Purification	Drainage
Flood Relief	Appraisals
Sewerage	Power Generation
Chicago	Hartford Bldg.

JAMES M. CAIRD

Cannon Bldg., Broadway and Second Streets
Troy, N. Y. Assoc. Am. Soc. C. E.

Chemist and Bacteriologist Water Analyses

SPECIALTIES—Tests of Filter Plants; Examinations and Reports upon Proposed Sources of Water Supply; the Copper Sulphate Treatment for Algae; Expert testimony.

AMBURSEN DAMS

Hydroelectric Developments
Water Supply and Irrigation Dams

DAMS ON DIFFICULT FOUNDATIONS

AMBURSEN CONSTRUCTION CO.

Incorporated
Grand Central Terminal, New York
Kansas City, Mo. Atlanta, Ga.

THE J. N. CHESTER ENGINEERS

J. N. Chester J. T. Campbell D. E. Davis
J. F. Laboon E. E. Bankson

Hydraulic and Sanitary Engineers

Water Works, Water Filtration, Appraisements
and Reports, Sewerage, Sewage Disposal,
Operation of Properties

Union Bank Building, PITTSBURGH, PA.

E. B. BLACK N. T. VEATCH, JR.
A. P. LEARNED E. H. DUNMIRE J. F. BROWN
C. I. DODD F. M. VEATCH

BLACK & VEATCH

Consulting Engineers

Sewerage, Sewage Disposal, Water Supply, Water
Purification, Electric Lighting, Power Plants,
Valuations, Special Investigations and Reports.

Kansas City, Mo., Mutual Building
307 South Hill St., Los Angeles, Calif. and
36 West 44th Street New York City

H. BURDETT CLEVELAND

Consulting Sanitary Engineer

Water Supply and Purification	Consultation Investigation
Sewerage and Sewage Disposal	Reports Evaluation
Refuse Disposal	Design
Industrial Waste Treatment	Supervision of Construction

TRANSPORTATION BUILDING

225 Broadway New York

HIRAM W. BLAISDELL

Consulting Engineer

Rapid Fine Sand Filtration, Machine Clean-
ing of Sand Filters, Conversion of Uncovered
Slow Sand Filters into Machine Cleaned
Rapid Fine Sand with a capacity of 25 m.g.a.d.
Sludge Removed from Sand Drying Beds and
Re-Sanding by Mechanical Means—Removal of
Sand from Circular Vats.

Hotel Sylvania, Philadelphia, Pa.

EDWARD S. COLE

Hydraulic Engineer

50 Church St., New York City

Burns & McDonnell Engineering Co.

McDonnell-Smith-Baldwin-Lambert

Consulting Engineers

Waterworks, Sewerage, Lighting, Appraisals.
Rate Investigations

Kansas City, Mo., Interstate Bldg.
Los Angeles, Cal., Western Pacific Bldg.

CONARD AND BUZBY

William R. Conard J. Stewart Buzby
322 High St., Burlington, N. J.

Inspections and Tests of Materials

REPORTS	SPECIFICATIONS
DESIGNS	INSPECTIONS
	TESTS

<p>FULLER & McCLINTOCK <i>Engineers</i></p> <p>NEW YORK, 170 Broadway</p> <p>Philadelphia, Pa. Kansas City, Mo. Pennsylvania Bldg., Walsix Bldg., 15th and Chestnut Sts. 600 Walnut Street</p>	<p>CHARLES H. LEE <i>Consulting Hydraulic Engineer</i></p> <p>WATER SUPPLY Investigations, reports, estimates, designs and development. Underground water a specialty. Water rights, valuation, acquisition and consultations. Court or Commission appearances.</p> <p>58 Sutter Street, San Francisco, Calif.</p>
<p>ALBERT F. GANZ, Inc. CONSULTING ENGINEERS</p> <p><i>Electrolysis Surveys and Reports</i> <i>Corrosion Investigations</i> <i>Design of Mitigative Measures</i></p> <p>511 Fifth Avenue New York, N. Y.</p>	<p>F. B. LEOPOLD <i>Builder of</i></p> <p>Municipal Filter Plants</p> <p>Experience of 25 years and more than 200 Plants built insures Satisfaction</p> <p>House Bldg. Pittsburgh, Pa.</p>
<p>GORDON, F. G.</p> <p>SUCCESSOR TO MAURY & GORDON CONSULTING ENGINEERS</p> <p>Water Works Sewerage Power Plants Appraisals</p> <p>Monadnock Building Chicago Illinois</p>	<p>METCALF & EDDY ENGINEERS</p> <p>Harrison P. Eddy John P. Wentworth Charles W. Sherman Harrison P. Eddy, Jr. Almon L. Fales Arthur L. Shaw Frank A. Marston E. Sherman Chase</p> <p>Water, Sewage, Drainage, Refuse and Industrial Wastes Problems Laboratory</p> <p>Statler Bldg. Boston</p>
<p>HAZEN & WHIPPLE <i>Civil Engineers</i></p> <p>Allen Hazen Malcolm Pirnie C. M. Everett L. N. Babbitt</p> <p>WATER WORKS Design, Construction, Operation, Valuations, Rates</p> <p>25 W. 43rd Street - New York City</p>	<p>ARTHUR L. MULLERGREIN CONSULTING ENGINEER</p> <p><i>SPECIALIST IN</i></p> <p>Electric Light, Power and Water Pumping</p> <p>555 Gates Bldg. Kansas City, Mo.</p>
<p>NICHOLAS S. HILL, Jr. CONSULTING ENGINEER</p> <p>WATER SUPPLY—SEWAGE DISPOSAL— HYDRAULIC DEVELOPMENTS.</p> <p>Reports, Investigations, Valuations, Rates, Design, Construction, Operation, Management Chemical and Biological Laboratories.</p> <p>112 E. 19th St., New York City</p>	<p>PEARSE, GREELEY & HANSEN HYDRAULIC AND SANITARY ENGINEERS</p> <p>Water Supply, Water Puri- fication, Sewerage, Sewage Treatment, Refuse Disposal, Investigations, Reports, De- signs, Construction Supervi- sion, Appraisals and Consul- tation.</p> <p>6 North Michigan Ave., Chicago, Illinois</p>
<p>William Gray Kirchoffer Sanitary and Hydraulic Engineer</p> <p>Madison, Wis.</p> <p>Designs for development of underground water supplies, wells with concrete screens, high efficiency air lift pumps, and iron removal plants.</p>	<p>THE PITOMETER COMPANY <i>Engineers</i></p> <p>Water Waste Surveys Trunk Main Surveys Water Distribution Studies Penstock Gaugings</p> <p>50 Church St. New York City</p>

ALEXANDER POTTER,
CONSULTING ENGINEER

Specialties: Water Supply and Sewerage

50 Church St. - - New York City

Telephone 5301 Cortlandt

WATER ANALYSIS

Our Laboratories are equipped with standardized apparatus for water analyses.

Our graduate chemists render dependable reports.

VAN CLEVE LABORATORIES, Inc.

322 So. 4th St., Minneapolis, Minn.

CLYDE POTTS

M. Am. Soc. C. E.

CONSULTING SANITARY ENGINEER

30 Church Street - - New York

Sewerage and Sewage Disposal,
Water Works and Water Supply,
Reports, Plans, and Estimates.

CORNELIUS C. VERMEULE

Consulting Engineer

Water Supply Sewerage

Investigation, Design,
Construction, Evaluation

38 Park Row New York

Sanborn & Bogert

CONSULTING ENGINEERS

Water Supply, Sewerage,
Dams, Tunnels and Founda-
tions. Concrete Structures.

New York 30 Church St.

Weston & Sampson

Robert Spurr Weston G. A. Sampson

Consulting Engineers for Water Supply, Water
Purification, Sewerage, Disposal of Sewage and
Municipal and Factory Wastes. Operation of
Purification Plants and Sanitary Analyses.

14 Beacon St. Boston, Mass.

Scofield Engineering Co.

CONSULTING ENGINEERS

Water, Gas, Electric Plants
and Distribution Systems

Appraisals, Valuations and Reports
Design—Supervision—Operation

PHILADELPHIA, PENNA.

GILBERT C. WHITE CO.

Consulting Engineers

Gilbert C. White, C. E., Pres.

M. Am. Soc. C. E.

M. Am. Soc. M. E.

Clarence E. Boesch, C. E.
M. Am. Soc. C. E.

Cecil C. Fulton, Jr.,
C. E.

WATER WORKS
POWER PLANTS
SEWERAGE

STREET IMPROVEMENTS
ASPHALT ANALYSES
ELECTRIC LIGHTING

DURHAM, N. C.

CAN

You afford

NOT

**to have your ad. in
this space**

THOS. H. WIGGIN

CONSULTING ENGINEER

415 Lexington Avenue, New York City

Tel. Vanderbilt 5248

Reports, Designs, Supervision, Valuation:
Water Supply, Sewerage, Canals, Flood
Control, Tunnels.

ADVERTISING

in this JOURNAL means

MORE BUSINESS

WANTED

POSITIONS HELP

The Association has frequent applications from competent men looking for positions. Let us know your needs and we will try to put you in communication with the right party.

Inquire of Secretary's Office, 170 Broadway, New York City

POSITION DESIRED

Superintendent of water plant. Twenty-three years general water works experience. Consisting of fifteen years accounting and eight years superintending operation and distribution system. Employed at present. Age 44 years.

Inquire of Secretary's Office, 170 Broadway, New York, N. Y.

POSITIONS VACANT

Two men, preferably graduates in Civil or Sanitary Engineering, with experience, capable of analyzing water and industrial wastes. Also two junior Sanitary Engineers. For work in vicinity of Pennsylvania. Give details of training, experience, personal facts, references and salary in first letter.

Inquire of Secretary's Office, 170 Broadway, New York, N. Y.

POSITION WANTED

Chemist and Bacteriologist with 25 years' experience in charge of water filter plants desires a change due to political upheaval in city of present position. M. I. T. 1901. Present salary \$4000. Experience covers waters in east and middle west. Would like position as head of laboratory or in charge of operation.

Inquire of Secretary's Office, 170 Broadway, New York, N. Y.

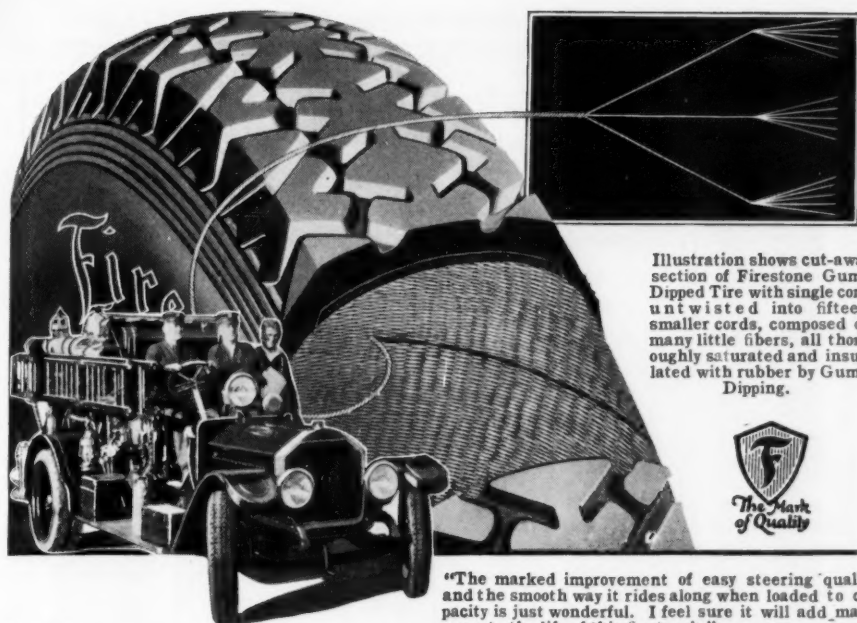


Illustration shows cut-away section of Firestone Gum-Dipped Tire with single cord untwisted into fifteen smaller cords, composed of many little fibers, all thoroughly saturated and insulated with rubber by Gum-Dipping.



"The marked improvement of easy steering quality and the smooth way it rides along when loaded to capacity is just wonderful. I feel sure it will add many years to the life of this fire truck."

A. J. ROBINSON, Chief,
Clinton, Mass.

Why Firestone

Dips the Cords of the Carcass in a Rubber Solution


In the old Fabric Tire, internal friction was excessive and mileage low, due to the square-woven construction of the fabric being impossible to insulate with rubber.

Then came the Cord Tire, with cords in each ply laid parallel—no interwoven cross-threads—permitting much greater insulation of the cords, one from another. This materially reduced friction and more than doubled tire mileage. But the small cords were not insulated with rubber and destructive friction within the cord was not overcome. After much research Firestone chemists found a method of insulating every fiber of every cord with rubber and called it "Gum-Dipping." By this process the cords of the carcass are dipped in a rubber solution which penetrates to the innermost fibers, protecting Firestone Tires from the fatigue of high speed driving.

Call on the Firestone Dealer today. Let him save you money and serve you better.

MOST MILES PER DOLLAR

AMERICANS SHOULD PRODUCE THEIR OWN RUBBER. *Harvey Firestone*

	<p style="text-align: center;">WELL SCREENS THAT DO NOT CORRODE</p> <p>Johnson Well Screens are now made from Anaconda Red Brass—an ideal material. It will not dezincify. It will not lose its strength, but will last indefinitely under all conditions.</p> <p>By using the Johnson you eliminate costly replacement of screens or drilling new wells. Remember, the screen is the “business end” of the well.</p> <p>Let us send you full details.</p> <p style="text-align: center;">EDWARD E. JOHNSON, INC. 2304 Long Avenue ST. PAUL, MINNESOTA</p>	
---	--	--

Warren Foundry and Pipe Company
(Formerly Warren Foundry and Machine Co.)

Manufacturers of

Cast Iron Pipe

Bell and Spigot Flanged
Special Castings and Fittings, Sizes 3" to 60"

Our Motto for 67 years “Quality First”

Sales Offices

11 Broadway, New York 201 Devonshire St., Boston, Mass.

Water Gas Sewers Drains Railroad Culverts
Also Flexible Joint Pipe

Works: Phillipsburg, N. J.

The joint that licked a hurricane---



The Florida hurricane last September blew away the supports under this line of 8-inch McWane pipe across a creek, but the Precalked Joints held.

Good proof this, of the strength and flexibility of McWane Precalked Joints. With considerable justification, therefore, you might call this pipe *hurricane-proof!*

One thing sure, the McWane idea has swept the country like a hurricane. Over 15 million feet installed in the past 5 years, in 48 states.

Sizes: 1¼ through 8 inches. Standard lengths. Precalked Joint fittings.

Investigate this nationally famous, nationally used factory-made joint cast iron pipe. Underwriters-approved.



This picture shows the 8-inch line of McWane Pipe across the creek, before it was hit by the hurricane.

McWANE CAST IRON PIPE CO.

BIRMINGHAM, ALA.

DISTRICT OFFICES:

819 Bankers Tr. Bldg.
Philadelphia, Pa.

208 S. LaSalle St.
Chicago, Ill.

1807 Santa Fe Bldg.
Dallas, Texas

PACIFIC STATES CAST IRON PIPE CO., Provo, Utah
608 Subway Terminal Building, Los Angeles, Calif.



GOLDEN-ANDERSON

Patent Automatic Cushioned Controlling Altitude Valves



We have enlightened many a water user in municipalities, in industrial plants and on railroads, as to the adaptability of these Golden-Anderson Valves, and as to their function of SAVING, and of eliminating troubles.

For automatically maintaining Uniform Stage of Water in Tank, Reservoir or Standpipes. Doing away with the annoyance of Freezing and Float Fixtures inside or outside of Tanks.

"Three Ways of Closing These Valves:"

- 1st—Automatically, by water
- 2nd—By Electricity, if desired
- 3rd—By Hand

May also be arranged to automatically close when a break occurs in the mains. When necessary they may be so connected as to "work both ways" on a single line of pipe.

No valves or fixtures inside or outside.

Sizes to 30 in.



Remember!

"HOSTS OF REFERENCES"

Valves cushioned at all times by air and water
No water hammer or bursting mains

"Made with stop starter attachment for centrifugal pumps"

GOLDEN-ANDERSON Automatic Cushioned Water Regulating Valves

for high or low pressure service are a necessity for modern water works and railroads.

Positive in action and perfectly cushioned both in opening and closing.

Will maintain a constant pressure regardless of the volume of the initial flow. When fitted with electrical attachment valve can be instantly opened to full area from any number of distant points, thus insuring full pressure in case of fire, etc.

Sizes to 30 in.



GOLDEN-ANDERSON

Patent Automatic Cushioned Controlling Float Valves

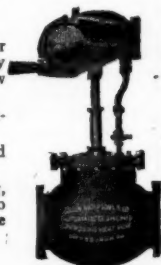
They carry a constant water level in feed water heaters by perfectly controlling the flow of makeup water.

Operated by protected enclosed copper float.

Cushioned by both air and water.

Operate without hammering, sticking or chattering. No metal to metal seats. Made angle or straightway.

Sizes 1 in. to 30 in.



GOLDEN-ANDERSON Pat. Automatic Cushioned Water Float Valves

1. Automatically Maintain Uniform Water Levels in Tanks, Standpipes, etc.

2. Instantly Adjusted to Operate Quickly or Slowly.

3. Floats Swivel to any Angle—Most Satisfactory Float Valves Known.

4. No Metal-to-Metal Seats—No Water Hammer or Shock.

5. Cushioned by Water and Air.

Sizes to 30 in.



GOLDEN-ANDERSON Patent Automatic Double Cushioned Check Valve

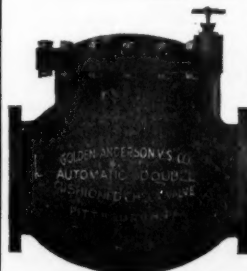
Automatically prevents reverse flow of pressure.

Perfectly cushioned to prevent shock or hammer.

Especially adapted for water works to prevent disastrous reverse flow of pressure due to pumps stopping.

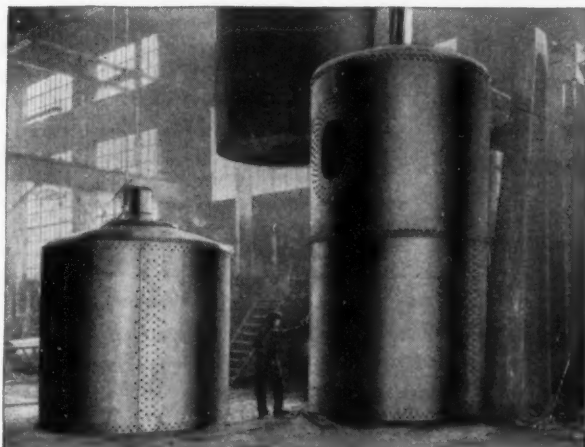
Arranged so that quick or slow operating may be obtained.

Sizes to 30 in. Angle or Globe



Golden-Anderson Valve Specialty Co., 1215 Fulton Bldg., Pittsburgh, Pa.

One of Biggs six hydraulic riveters. This "bull" has an 18'6" gap and exerts a pressure of 150 tons, driving rivets 1½ inch in diameter.



Biggs Riveted Steel Pipe is safer and more economical than pipe construction of any rigid material. A few outstanding reasons:

- 1 If a Biggs conduit *should* fail, the slight tear could be repaired quickly, completely, and economically and without discontinuing the water service.
- 2 Biggs Riveted Steel Pipe can be taken up, reconditioned, and relaid at minimum cost.
- 3 New connections can be made at minimum cost and with a minimum disturbance to water service.
- 4 Biggs Steel Plate Construction affords the highest degree of safety, as well as of flexibility, under all conditions.

THE BIGGS BOILER WORKS CO.

General Offices and Works

Akron 23, Ohio

Eastern Sales Office

300 Madison Ave.
New York City

Chicago Office
35 S. Dearborn
Street

Biggs data should be of value to you in your engineering problems. Write for it—no obligation.



BIGGS
Riveted and Welded
STEEL PIPE

ALUMINUM SULPHATE

Standard Filter Alum



*Shipments are made
from a country-wide
chain of plants
and stations.*

Lump for solution feed Special ground for dry feed

Quantity output and processes which protect the Standard Purity of the Company's product enable the user of Filter Alum to place his orders with General Chemical Company with implicit confidence.

And his good judgment is confirmed by the majority of purchasers of this important product.

ADDRESS THE NEAREST SALES OFFICE

GENERAL CHEMICAL COMPANY
40 RECTOR STREET New York

Cable Address, Lyncurgus, N.Y.

BALTIMORE · BUFFALO · CHICAGO · CLEVELAND · DENVER · EASTON
LOS ANGELES · PHILADELPHIA · PITTSBURGH · PROVIDENCE · SAN FRANCISCO · ST. LOUIS
THE NICHOLS CHEMICAL CO., LTD., MONTREAL

CLEAN YOUR WATER MAINS

One does not have to be an expert mathematician to figure out that a clogged water main calls for a stronger pressure and that in turn calls for more coal—and literally burning up money. We can show you how to get dollar for dollar value out of every ton of coal. We can show you how to clean the water mains quickly and cheaply. Send us your address—that's all we ask of you.

National Water Main Cleaning Co.

CHURCH AND DEY STREETS
NEW YORK CITY



*Types of Cast Iron
Culvert Installations*

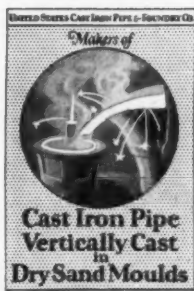


Use deLavaud Centrifugally Cast Culverts for Permanence ... and Economy

THE great compressive strength of deLavaud cast iron culverts is an important point where a heavy fill exists.

Their light weight makes them easy to handle and install—the smooth interior surface produced by the deLavaud centrifugal method of casting gives them an increased run-off capacity.

Many construction engineers specify cast iron culverts on account of their high resistance to corrosion. Their strength results in permanence and the elimination of maintenance costs.



Write for full details

United States Cast Iron Pipe and Foundry Company

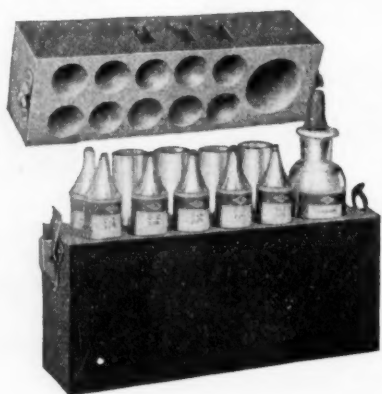
SALES OFFICES

Philadelphia	New York
Chicago	San Francisco
Birmingham	Pittsburgh
Buffalo	Dallas
Cleveland	Kansas City
Minneapolis	

General Offices:

Burlington, New Jersey

ENSLOW CHLORINE COMPARATOR



**For Determining
Free Chlorine
In Water, Sewage,
and Industrial
Wastes**

The Enslow Comparator, which was developed in cooperation with Mr. L. H. Enslow, Research Engineer of the Chlorine Institute, embodies a new principle in that it is designed to eliminate the effects of color and turbidity in the sample. It is therefore ideally adapted for determining free chlorine in raw water, sewage and industrial wastes, as well as in filtered water. The readings are made by comparing the test sample with permanent standards.

Complete information sent on request. Price \$12.50 F. O. B. Baltimore.

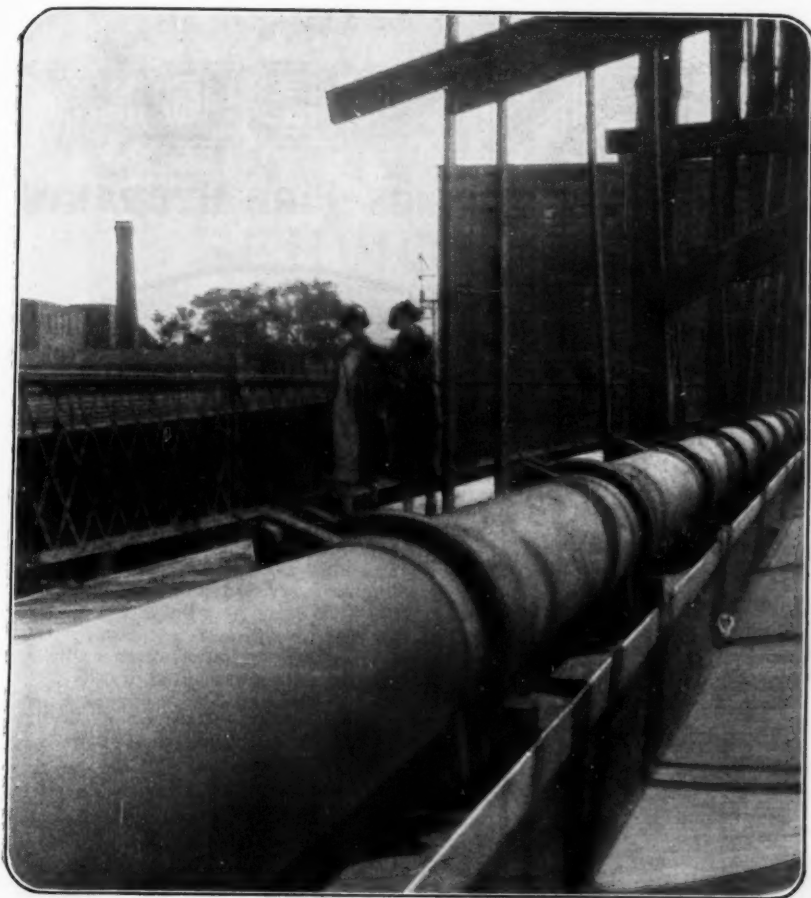


A copy of our "ABC of Hydrogen Ion Control" will be sent free on request. It explains the meaning of H-Ion Control in simple language and includes descriptions of all LaMotte Equipment with detailed information on its use.

LAMOTTE CHEMICAL PRODUCTS CO.

424 LIGHT ST.

BALTIMORE, MD., U. S. A.



The only 100% cast iron pipe

It makes its own joints. Easier to lay. Quicker to lay. No bell holes to dig. No pouring. No joints to calk. Nothing in its machined iron-to-iron joints to work loose nor to deteriorate. Laid anywhere, in any season. Thousands of miles installed every year.

.. Joints as tight as the wall of the pipe itself ..

1. The very nature of its joint construction recommends Universal Cast Iron Pipe as a safe pipe, many authorities say "the only safe pipe" for bridge and river crossings. Its machined iron-to-iron joints remain unaffected by jar, vibration and exposure to the elements . . .

Put your water supply, fire protection and sewage disposal pipe problems up to our nearest office.

UNIVERSAL CAST IRON PIPE

No bell holes to dig: No joints to calk

THE CENTRAL FOUNDRY COMPANY

Subsidiary of The Universal Pipe and Radiator Company

Graybar Building, 429 Lexington Avenue

Chicago Birmingham New York Dallas San Francisco

KENNEDY

VALVES~PIPE FITTINGS~FIRE HYDRANTS



Let's Go
Chicago 1927

A type for every water works service

Waterworks superintendents all over the country can testify to the uniformly dependable service and trouble-free operation of Kennedy equipment. On the water supply and fire protection systems of hundreds of municipalities, Kennedy Valves and Fire Hydrants are giving thorough satisfaction, promptly responding to every demand, and efficiently meeting every emergency.

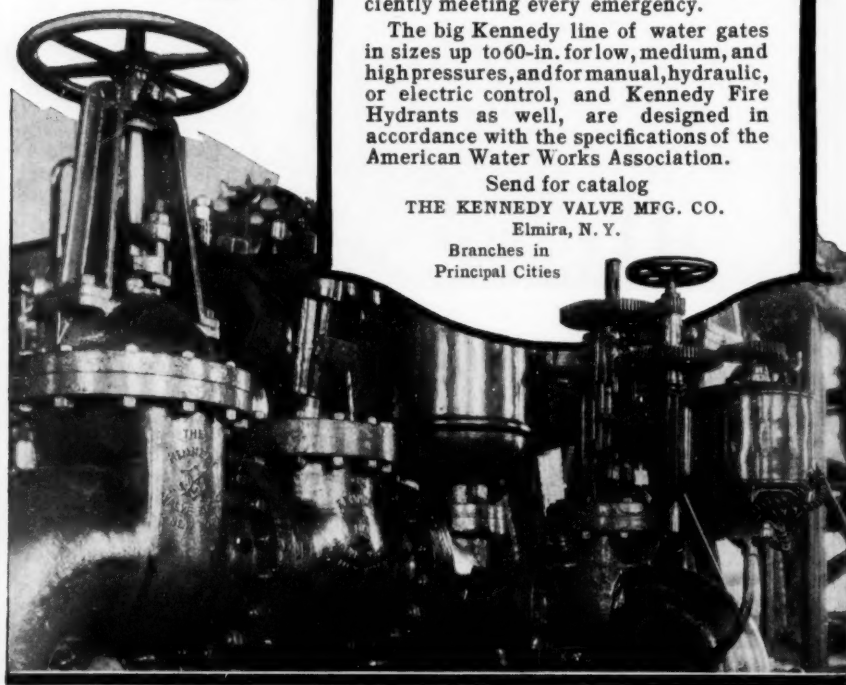
The big Kennedy line of water gates in sizes up to 60-in. for low, medium, and high pressures, and for manual, hydraulic, or electric control, and Kennedy Fire Hydrants as well, are designed in accordance with the specifications of the American Water Works Association.

Send for catalog

THE KENNEDY VALVE MFG. CO.

Elmira, N. Y.

Branches in
Principal Cities



CEMENT LINED SERVICE PIPE

Does not depend on water pressure to hold it in shape.

Is not injured by careless handling or back-filling.

Uses standard fittings.

Sixty years use proves it rustless.

Has no harmful effect on any water.

Now standard in dozens of the most progressive cities and towns.

Inexpensive.

CEMENT LINED PIPE CO.
LYNN, MASS.

MANUFACTURERS OF

Gate Valves Sluice Gates Check and Foot Valves

Motor and Hydraulic Operated Valves

ALL SIZES—EVERY STYLE—ANY PRESSURE

Fire Hydrants

Simple in Construction

Efficient

Frost-Proof

"All parts removable without digging up hydrant. Special device prevents street from being flooded should standpipe be broken. Minimum expense to install and maintain."

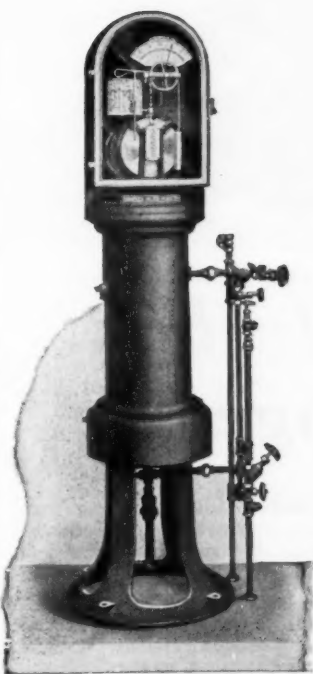
Office & Works Troy, N.Y.

BRANCH OFFICES

**New York
Chicago
Boston
Philadelphia
Pittsburgh
Kansas City
Atlanta, Ga.**

- 81-83 Fulton St.
- No. 731-733 The Rookery
- 1112 Tremont Bldg.
- Harrison Building
- 815 Oliver Bldg.
- R. A. Long Building
- 4th National Bank Bldg

Is Your Water Works Pumping Station Operating Efficiently



Simplex Meter Register

Every up-to-date water works manager holds it essential to know at all times the efficiency of his plant. If pumping, he must know the fuel consumed and the amount of water pumped. Pump counters are unreliable, on account of pump slip varying from zero to 40% in reciprocating pumps, and on centrifugal pumps they are inoperative. If the supply is by gravity, he must know the quantity of water flowing.

Simplex meters provide for either one of these conditions by giving a continuous record of the flow of water. It is simple, rugged, reliable and accurate from the maximum down to 5% of the maximum flow, without material loss of pressure.

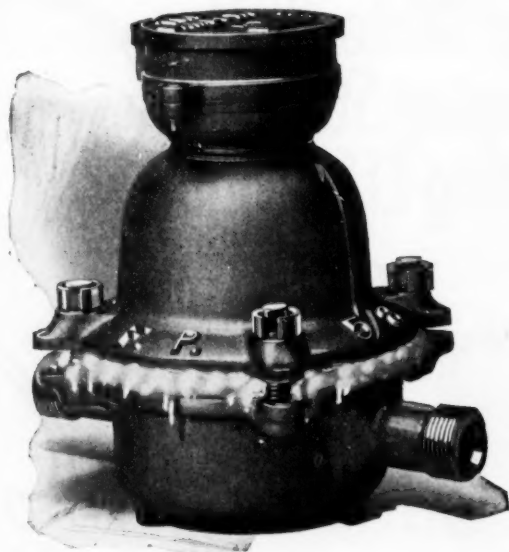
Interesting data on the "Simplex Venturi Tube Meter" sent upon request

SIMPLEX VALVE AND METER CO.

Manufacturers of Meters for Water, Sewerage and other liquids, Rate
Controllers, Automatic Air Valves, Regulating Valves, and
Hydraulic Apparatus of Special Design

6759 UPLAND STREET

PHILADELPHIA, PA.



FROZEN!—but not damaged

Here is an actual photograph of a LAMBERT Frost-Proof Meter which has been frozen to an extent that would put the ordinary meter completely out of commission.

This is made possible by a patented, non-corrosive yielding bolt device which allows the upper and lower casing, disc chamber and gear train to part without damaging the meter in any way. Five minutes' labor the only repair cost.

The expense and annoyance from frozen water meters can be eliminated for all time through the installation of the LAMBERT Frost-proof.

It has been proved that the LAMBERT is the easiest water meter to take apart and put together again as well as the simplest, most reliable and accurate.

If you are interested in other types of meters, we make one for every requirement.

THOMSON METER CORPORATION

SALES OFFICE, 50 E. 42nd STREET

NEW YORK CITY, N. Y.

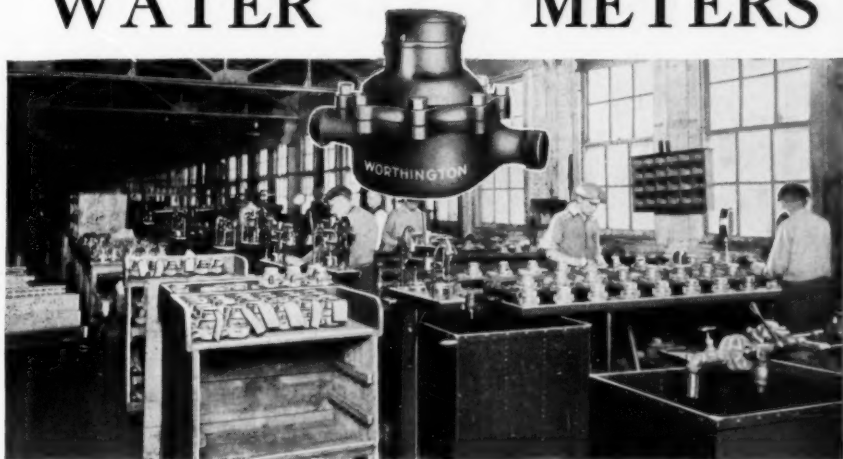
LAMBERT

**FROST PROOF
METERS**

WORTHINGTON



WATER METERS



View of Small-Meter Testing Department, Worthington Works, Harrison, N. J.

THERE is a Worthington Water Meter for every requirement from the measuring of small customer flows to the measuring of flows of 10,000,000 gallons per 24-hours.

Types of Worthington Meters

Disk Meters—furnished with open train or enclosed oil train. Smaller sizes can be fitted with frost protector.

Turbine Velocity Meters

Compound Meters

Hot-water Meters for boiler-feed lines

Oil Meters for hot oil and for cold oil

Stocks of meters are carried in our branch houses in all parts of the country to insure prompt service.

Pumps and Pumping Engines	Compressors	Condensers
Oil and Gas Engines	Feedwater Heaters	Water and Oil Meters

WORTHINGTON PUMP AND MACHINERY CORPORATION

115 BROADWAY, NEW YORK. Branch Offices in 24 Cities

AMERICAN WATER SOFTENER COMPANY

Successor To

NEW YORK CONTINENTAL JEWELL FILTRATION COMPANY

More Than 500 Municipal Filtration Plants Installed

GRAVITY FILTERS PRESSURE FILTERS

FILTER EQUIPMENT OF EVERY DESCRIPTION

Dry Chemical Feeders	Control Tables
Wet Feed Apparatus	Effluent Controllers
Loss of Head Gauges	Rate of Flow Gauges
Iron Removal Plants	Water Softening Plants
Chlorinators	Zeolite Water Softeners

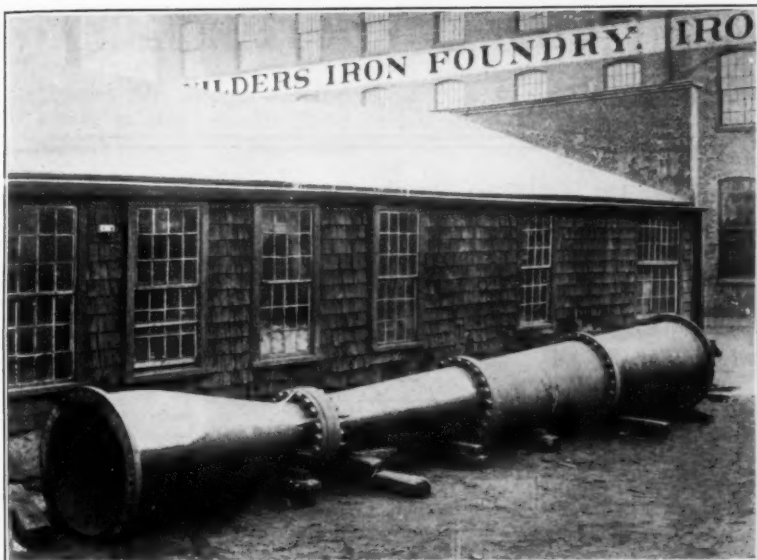
Write for Our Catalogues and Bulletins

AMERICAN WATER SOFTENER COMPANY

Fourth and Lehigh Avenues

PHILADELPHIA, PENNA.

ORIGINATORS OF MECHANICAL FILTRATION



1891—Venturi Meter Tube No. 1.—East Jersey Water Co.

At the age of 36—

VENTURI METER TUBE NO. 1 is still in service at the East Jersey Water Company along with its ORIGINAL VENTURI REGISTER installed there two years later.

Keeping pace with water works progress the Venturi has been steadily improved but the same qualities which continue the original apparatus in service maintain the nation-wide reputation for accuracy and durability which Venturi Meters today enjoy.

May we send you our latest Bulletin for waterworks service,—“The Venturi Meter for Main Pipe Lines”?



Let's Go! Chicago

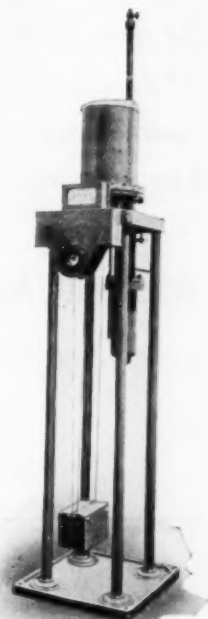
We cordially invite those attending the Chicago A. W. W. A. Convention to stop at our booth and see the latest Venturi Meters and Controllers.

BUILDERS IRON FOUNDRY

“Builders of the Venturi for 36 years”

Providence

Rhode Island



1893—Original Register used with Meter Tube No. 1.

IMPORTANT

THE Association has run short of certain numbers of the Journal. Any members who are not interested in preserving their back numbers for January and March, 1920 and 1922, and January, March, May and July, 1924, and are willing to return same, will be acting to the benefit of the Association.

AMERICAN WATER WORKS ASSN.,
170 Broadway,
New York City.

STANDARDIZE ON THE CLARK METER BOX

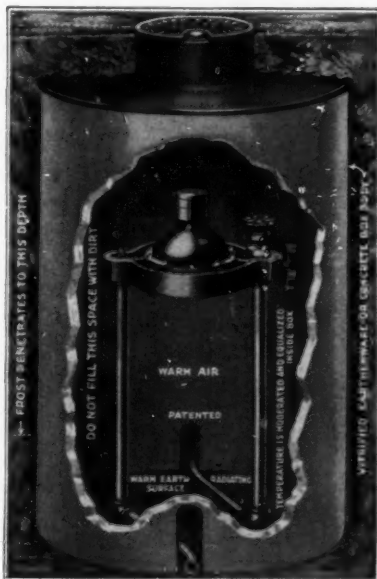
Houses all meters whether placed in boulevard, sidewalk or street in the same uniform and systematic manner and large meters as well as small ones.

A type and size to meet every climatic condition.

Why experiment when The Clark Meter Box has proven successful in thousands of Water Departments for over twenty years?

Perfect Locking Device

is operated by one third turn of key—It is always operative although not used for years. Due to the bronze construction of all working parts, it is not necessary to keep oiled. No guesswork as to the position of Lock, and no bothersome fumbling in getting box open. Operating Key is provided with double prong on handle for engagement into notched recess on lid for quick removal.



Meter Coupling Yoke

provides — Rigidity of supply pipes with meter in service or when removed; elimination of all strains and consequent leaks, with ample provision for expansion and contraction in pipe line. When control valve as illustrated is used curb cock and box may be eliminated — saving not only the cost thereof but pipe fittings and labor. Only four parts. Assembly is made without bolts, rivets or screws, and without aid of tools.

Protection from frost even at 60° below zero

Send for catalog 24—a treatise on modern water works practice



H. W. CLARK COMPANY

Manufacturers Water Works Equipment

MATTOON, ILLINOIS, U. S. A.

Meter Boxes

Vitrified Box Bodies

Forms for Concrete Bodies

Meter Couplings

Meter Coupling Yokes

Service Boxes

Repair Lids

Vise for Brass Pipe

Valve Boxes

Valve Housings

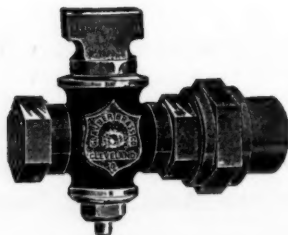
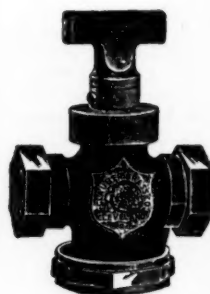
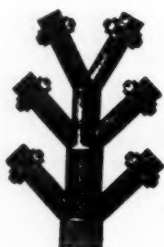
Meter Testing Machines

Trouble Finding Instruments



⁶⁶GLAUBER⁷⁷ BRASS GOODS

NEVER FAIL TO MAKE A GOOD
IMPRESSION - ONE THAT LASTS



GLAUBER BRASS MFG. CO.
Cleveland, Ohio

The A. P. Smith Manufacturing Company

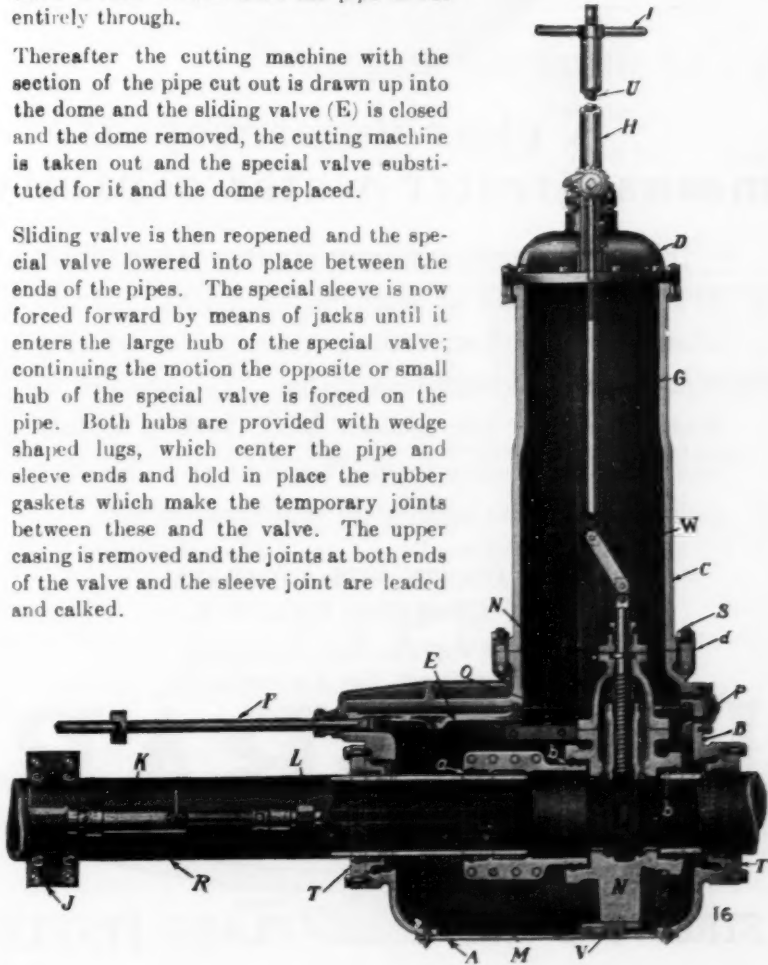
East Orange, New Jersey

Manufacturers of Water Works Specialties, one of these specialties shown herewith, namely a Machine for inserting 4", 6" and 8" valves in existing straight lines of pipe under pressure. The machine is made in other sizes as follows: No. 2 for inserting 8", 10" and 12" valves, No. 3 for inserting 14", 16", 18" and 20" valves, No. 4 for inserting 24" horizontal valves and we are now designing a machine for inserting 30" valves.

The pipe is cut about one-half through and the special sleeve is then bolted around the pipe, the end of the sleeve being placed within a fraction of an inch of the cutting tool; the Inserting Machine is then attached around the pipe and the sleeve completely enclosing the cutting mechanism. The shaft is then rotated until the pipe is cut entirely through.

Thereafter the cutting machine with the section of the pipe cut out is drawn up into the dome and the sliding valve (E) is closed and the dome removed, the cutting machine is taken out and the special valve substituted for it and the dome replaced.

Sliding valve is then reopened and the special valve lowered into place between the ends of the pipes. The special sleeve is now forced forward by means of jacks until it enters the large hub of the special valve; continuing the motion the opposite or small hub of the special valve is forced on the pipe. Both hubs are provided with wedge shaped lugs, which center the pipe and sleeve ends and hold in place the rubber gaskets which make the temporary joints between these and the valve. The upper casing is removed and the joints at both ends of the valve and the sleeve joint are leaded and calked.





A clear water-way means greater water capacity

It will be readily understood why LOCK BAR STEEL PIPE has so much more carrying capacity. Obstructions to flow, causing friction, and reducing capacity are practically eliminated. The absence of obstruction and the smooth inner surface further eliminate opportunity for the building up within the pipe of deposits to restrict the pipe area.

EAST JERSEY PIPE COMPANY
7 Dey Street, New York, N. Y.

WESTERN STEEL PIPE COMPANY
444 Market Street, San Francisco, Cal.

LOCK-BAR

Before  *Closing*

STRONG AS THE PLATE ITSELF

EDSON

DIAPHRAGM PUMP SPECIALTIES

Hand and Power Outfits

LIGHT PORTABLE TRAILER PUMPS

HEAVY DUTY One or Two Pump UNITS
with 3-inch or 4-inch Suction

Insist on GENUINE EDSON
Pumps, Suction Hose, Dia-
phragm with Bead, etc.

Write for Catalogue T.

EDSON MANUFACTURING CORP.

Main Office and Works
375 Broadway, Boston
142 Raymond St., Brooklyn, N. Y.

BELLE ALKALI CO.

BELLE, W. VA.

CHLORINE

Highest Purity Only
In "White Cap" Cylinders

CAUSTIC SODA

Solid and Flake

BELLE BRAND

Arnold, Hoffman & Co. Inc.

Sole Agents

Providence New York Boston
Philadelphia Charlotte



National Cast Iron Pipe Company

General Office and Foundries
BIRMINGHAM, ALABAMA

Manufacturers of Sand Cast and deLavaud
Centrifugally Cast, Cast Iron Water and Gas

PIPE

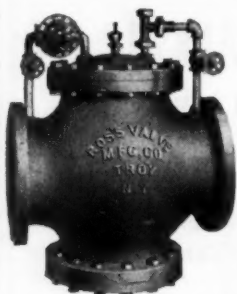
Also Fittings, Flange Pipe, Flange Fittings and Special Castings

We are featuring our 2' Bell and
Spigot Cast Iron Service Pipe in
6' lengths with prepared joint.
Write or wire us for information.

SALES OFFICES:

Chicago.....717 Peoples Gas Bldg.
Kansas City, Mo....603-04 Land Bank Bldg.
Dallas.....1215 Santa Fe Bldg.
Los Angeles.....903 Hellman Bank Bldg.
Jacksonville, Florida
1409 Barnett National Bank Bldg.
Salt Lake City, Utah.....417 Kearns Bldg.

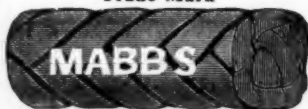
Stocks Carried at Chicago, Illinois, Kansas City, Missouri and Dallas, Texas



Automatic Pressure Control Valves
Feed Water Filters
Portable Fire Hydrant Heads
Hydraulic Engines
Hydraulic Booster Pumps

ROSS VALVE MFG. CO., INC. TROY, N. Y.
 ESTABLISHED 1879

Trade Mark



Reg. U. S. Pat. Off.

Water Works Engineers

Do You Want a Packing that will NEVER Cut or Score Your Rods, Shafts, or Plungers, and Will Last For Years?

Then send us an order for the MABBS RAWHIDE PACKING which never becomes hard or glazed, and will save you power and money. Any size put up in standard tin pails of 5-10-25 and 50-lbs. and in kegs and barrels of 100 and 200-lbs. Price \$2.00 per lb.

MABBS HYDRAULIC PACKING COMPANY
 431 S. DEARBORN STREET (Incorporated 1892) CHICAGO, ILLINOIS

DIAMOND BRAND SODA ASH for WATER TREATING

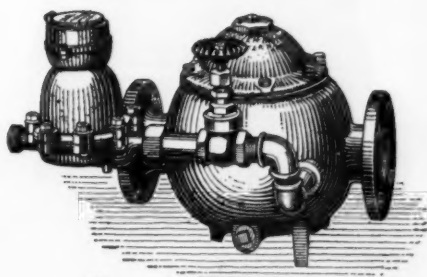


Diamond 58% Soda Ash is used by the largest municipal and industrial water treating plants in the country. Guaranteed over 99% Sodium Carbonate. The additional quality maintains it as the Standard.



Manufactured and Sold Direct to Consumer by
Diamond Alkali Company
 PITTSBURGH, PA.

Toledo, Ohio, Invested \$2730.00



Increased yearly income
\$20,471.32

As a result of installing Union Compounding Valves, Toledo, Ohio, has proven once more the increased revenue of this valve.

The first installation was on twenty-three meters of various types, there being thirteen 3-inch, eight 4-inch and two 6-inch. The monthly average billings before compounding increased after compounding 106 per cent, or \$20,471.32 based on one year. In every instance there was an increase, the highest being 608 per cent.

Union Compounding Valves stop the leaks in revenue by measuring the small flow. For comparatively small initial investment you can secure returns in increased revenue that will astonish you. Write for catalog.

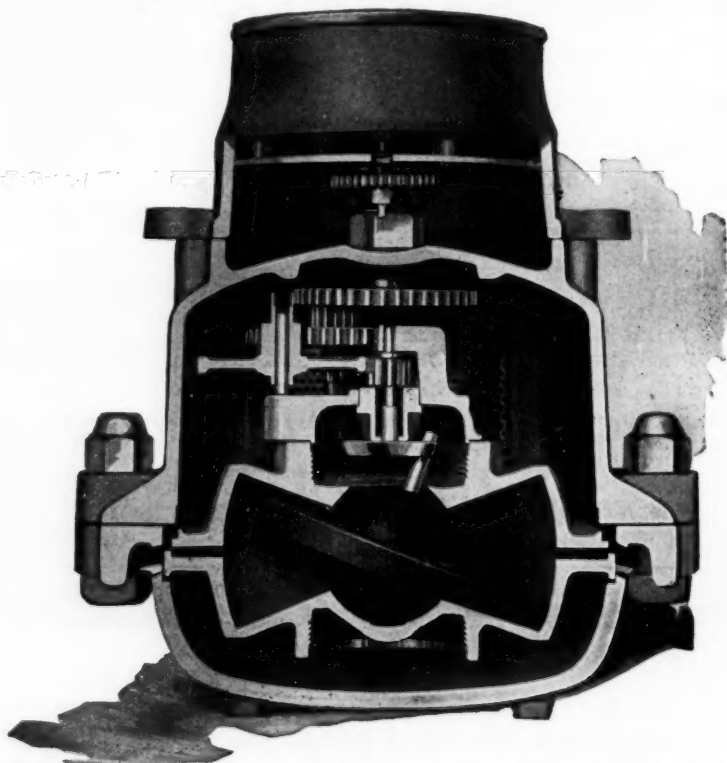
UNION WATER METER CO.

Established 1868

WORCESTER, MASS.

New York Office: 50 Church St. Philadelphia Office: 411 Bulletin Bldg.

AMERICAN AND NIAGARA WATER METERS WITH BREAKABLE FROST BOTTOMS (Patd.)



This sectional view shows a $\frac{5}{8}$ inch or house size meter cut at right angles to the pipe line. The breakable frost bottom has been broken by a freeze up.

NOTE:

1. How the breakable section of the bottom is entirely inside and independent of the meter flange. This allows the six flange bolts to be drawn directly up on the gasket. Meter is tight on highest pressures.
2. How the breaking of the frost bottom immediately releases the measuring chamber. No warping.
3. How the submerged gears can remain fixed in the ice, while their bearing shafts move downward. No breakage.

These and other points described in large illustrated catalogue. Write for your copy.

Write for catalog and prices

BUFFALO METER CO.
2914 Main St. **BUFFALO, N. Y.**

Niagara and American meters comply in all respects as to accuracy and capacity with the Standard Specifications of the American Water Works Association.

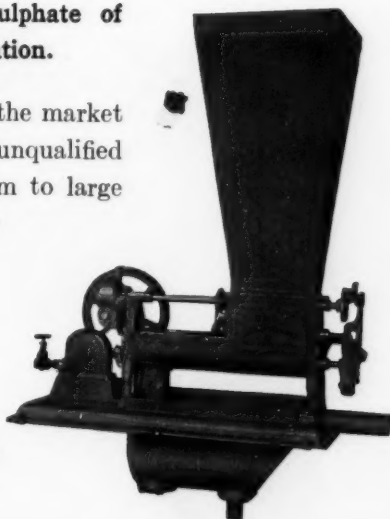
The Gauntt Dry Chemical Feeder

designed for feeding any dry material, especially Hydrated Lime and Sulphate of Alumina for water purification.

These machines have been on the market ten years and have met with unqualified success. We are furnishing them to large and small cities all over the country

*Write for Catalog No. 25
giving full description*

W. J. SAVAGE COMPANY, INC.
KNOXVILLE, TENN.



THE PRESUMPTIVE TEST

Bacto-Lactose Broth

A medium conforming to "Standard Methods" formula for determining gas production resulting from direct inoculation of water.

Bacto-Lactose Peptone Bile

An excellent medium for use in the presumptive test for colon organisms in water analysis, partially inhibitory for non intestinal organisms.

Bacto-Brilliant Green Bile Medium

A medium conforming to the formula of Muer and Harris, inhibitory for anaerobes and other organisms which tend to confuse results of the presumptive test.

Specify "DIFCO"

THE TRADE NAME OF THE PIONEERS

In the research and development of Bacto-Peptone and Dehydrated Culture Media

DIGESTIVE FERMENTS COMPANY

DETROIT, MICHIGAN, U. S. A.

N A S H W A T E R M E T E R S

DISC TYPE



NASH (Type K)

Carefully designed, well made, accurate and reliable. Both Frost and "Dixie" models.

ALL BRONZE CONSTRUCTION
BALANCED CONICAL DISC
ENCLOSED INTERMEDIATE
BREAKABLE FROST WASHER
and every other feature that test
and experience have proved to be
worth while.

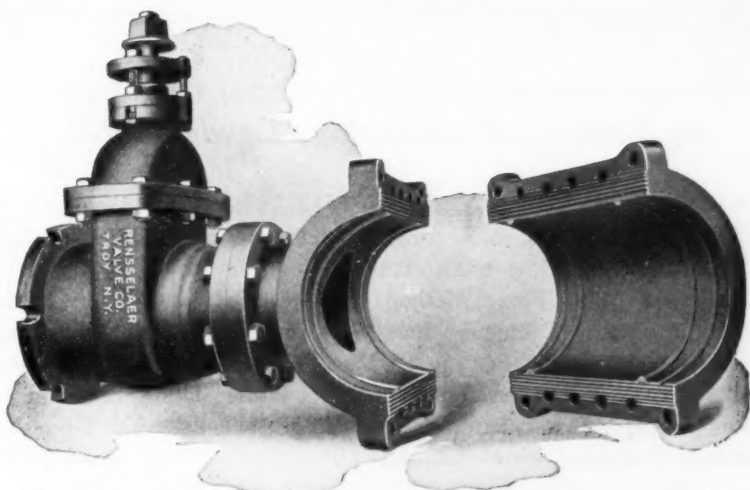
A special merit of the NASH is
the ease with which it can be
opened and taken apart for in-
spection or cleaning.

*Have you a Nash descriptive book-
let? If not, ask us to send you one.*

NATIONAL METER CO.

299 BROADWAY, NEW YORK

Chicago Boston
Cincinnati Atlanta San Francisco
Los Angeles San Antonio



SOME of the POINTS OF SUPERIORITY of RENSSELAER TAPPING SLEEVES

Require less lead for Calking
Easier to center on pipe before pouring
Give Extra Pipe Protection
Bolts require No Iron Washers
Each Size carefully designed for its Working Pressure
Can be used with all Standard Tapping Machines

Rensselaer Tapping Sleeves are the only Sleeves on the market which are built with two Raised Rings which are a part of the Sleeve Casting itself. These Rings are used as Stops for the Hemp or Jute against which the Lead is poured to make the joint. In other types of Sleeves, without Rings, the Lead, when poured, fills entire space up to point at which cut is made.

The Raised Rings also permit easier centering of Sleeves on Pipe, also permit revolving Sleeve on pipe making it easier to tighten nuts on bolts which connect the two halves of the Sleeve.

The Bolting Flanges on all Sizes of Rensselaer Sleeves are made the full length of the Sleeve, permitting a greater number of bolts to be used back of point calked, giving greater protection to pipe at point where piece is cut out. This is especially important as in some cuts a hole nearly one-half the size of pipe is cut away.

BOOK No. 11 GIVES FURTHER PARTICULARS

RENSSELAER VALVE COMPANY

TROY, N. Y.

BRANCH OFFICES

NEW YORK, Hudson Terminal Bldg,
 CHICAGO, Monadnock Block
 PITTSBURGH, Oliver Bldg.

LOUISVILLE, Starks Bldg.
 SEATTLE, Arctic Bldg.
 NEW ENGLAND, C. L. Brown, Northboro, Mass.

Transactions of the International Conference on Sanitary Engineering, London, 1924

*Distributed in
the United States
by the A. P. H. A.*

THE CONTENTS cover a wide variety of subjects, including State Sanitary Administration; Works for the Prevention of Malaria and Yellow Fever; Methods of Disposal of Sewage and Trade Wastes in Various Countries; Treatment of Sludge Arising from the Agitation Processes of Sewage Disposal; Fertilizing Value of Sewage Sludge; Sewerage and the Control of Storm Water; Design of Sedimentation Works; House Sanitation; Refuse Collection and Disposal; National Control of Water Sources.

Price, \$4.00

AMERICAN PUBLIC HEALTH ASSOCIATION

370 Seventh Avenue, - - New York City

The Public Health Engineering Section OF THE American Public Health Association

IS ONE OF THE ASSOCIATION'S OLDEST AND MOST IMPORTANT DIVISIONS

The Association extends an invitation to every sanitary engineer engaged in the control of the environment to become a member and become affiliated with the section of his profession. Members are entitled to all the services which the Association has to offer, including the American Journal of Public Health. This unique monthly publication gives you the various Committee reports of the Sanitary Engineering Section in addition to original articles and notes on the important developments in your field and also keeps you informed on important topics in all the allied fields of public health. Recent issues of the Journal have contained the following papers of interest to you:

Definitions for Sewerage and Sewage Disposal Practice; Water Supply and Purification, Report of the Committee; Values in the Control of the Environment; Sewage Analysis and its Interpretations; Bathing Places, Report of the Committee; Incinerator Specifications and Contract Tests.

Clip the coupon below for an application blank for membership or a sample copy of the Journal or both.

The American Public Health Association,
370 Seventh Avenue, New York City.

I am interested in membership in the Association. Please send me an application blank....

I would appreciate a sample copy of the American Journal of Public Health.....

Name.....
Address.....

MATHIESON

Industrial Chemicals

"Lest We Forget"

WATER chlorination, as a public health measure, is so well established that most municipal authorities now accept it at its face value.

But as time goes on, new men come into the field—there are new minds to train—new objections to overcome.

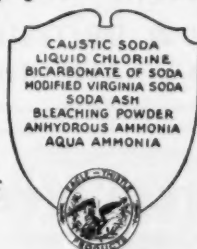
It is therefore fitting that, periodically, municipal buyers, as a group, should be reminded that before chlorination was introduced, New York City had a death rate from typhoid fever of 13.5 per 100,000 population. After chlorination was adopted, the death rate from typhoid dropped to 2.9—a reduction of practically 79%.

The experience of

New York was typical of the results secured by scores of cities throughout the country. The death rate reduction as a result of chlorination was 61% in St. Louis and 89% in Philadelphia—highs and lows that indicate how large has been the average reduction.

Just as New York was one of the first American cities to employ chlorination, it was also the first city to take deliveries of Liquid Chlorine in Mathieson Multiple-Unit Tank Cars, carrying fifteen one-ton units.

Mathieson Chlorine equipment has ever played an important part in the development of efficient water chlorination.



The **MATHIESON ALKALI WORKS Inc.**

250 PARK AVE. NEW YORK CITY
PHILADELPHIA CHICAGO PROVIDENCE CHARLOTTE CINCINNATI

Works: Niagara Falls, N. Y.—Saltville, Va.
Warehouse Stocks at all Distributing Centers

Deal Direct with the Manufacturer

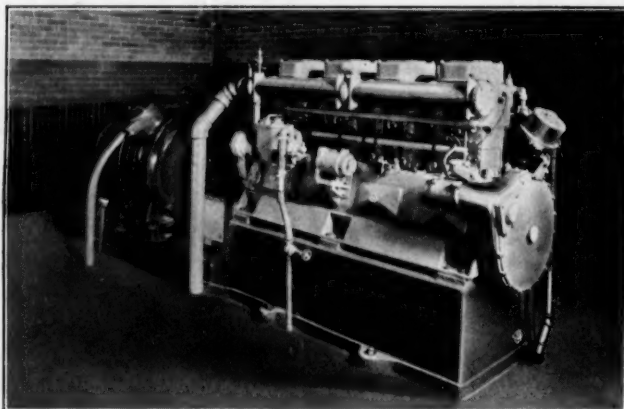
DO YOU KNOW WHEN YOUR POWER IS GOING TO FAIL?

Water Works with a Sterling on guard have full protection

**Sterling
High Duty**



**Internal
Combustion
Engines**



St. Catharines, Ont., 240 H.P., 8 cylinder Sterling engine connected 125 KW., 130 KVA, 1200 R.P.M. Alternator. Installed by Francis Hankin & Co. Ltd. of Montreal

STERLING ENGINE COMPANY

Dept. C-3

Buffalo, N. Y.

10 to 3000 H.P. for standby and peak load. 900-1200-1400 R.P.M.

SULPHATE OF ALUMINA

MANUFACTURED BY

THE JARECKI CHEMICAL CO.

CINCINNATI, OHIO

FOR FULL PARTICULARS APPLY TO

ISAAC WINKLER & BROTHER, Sole Agents

CINCINNATI, OHIO



WE ARE PREPARED TO FURNISH AND
INSTALL LONG-LIFE PRESSURE PIPE IN
ANY QUANTITY AND IN ANY LOCALITY.

PENSTOCK CONSTRUCTION COMPANY
SHARON, PA.

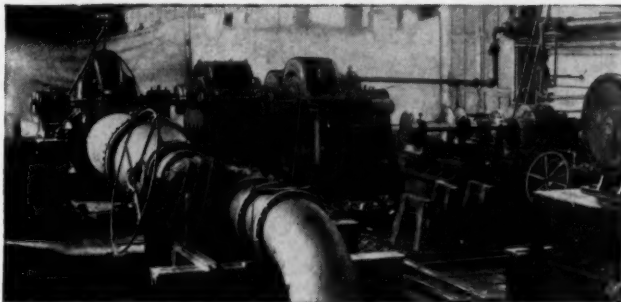
New York

St. Louis

Tulsa

Houston

The World's Largest Water Works Pumping Station



One of 4 De Laval turbine driven pumps for the Western Avenue Pumping Station on test at the De Laval Works. 75 M G D each against 150 ft. head.

THE water works system of the City of Chicago has a capacity of 1,300,000,000 gallons per day, of which 900,000,000 gallons can be delivered by De Laval pumping units located in the Chicago Avenue, Central Park, Springfield Avenue, and Western Avenue pumping stations. The Western Avenue Station, now being completed, is the largest municipal water works pumping station in the world, and will have a capacity of 300,000,000 gallons per day. Four De Laval steam turbine driven centrifugal pumps of 75,000,000 gallons per day capacity each against 150 ft. head are installed in this station. The photograph shows one of these units on test at the De Laval Works.

The highly satisfactory service rendered by De Laval centrifugal pumping units in Chicago is indicated by the number of repeat orders.

- June, 1920,—Two 40 MGD motor driven units for Chicago Avenue
- One 60 MGD turbine driven unit for Central Park
- Two 60 MGD turbine driven units for Springfield Avenue
- September, 1920,—Two 40 MGD motor driven units for Chicago Avenue
- 1923,—One 60 MGD unit for Central Park
- May, 1924,—Four 75 MGD turbine driven units for Western Avenue Station
- September, 1924,—One 60 MGD turbine driven unit for Central Park Station
- One 60 MGD turbine driven unit for Springfield Ave. Station

A comparison of the duties of the 60,000,000 gallon units bought in 1920, 1923, and 1925, all for the same steam pressure and superheat, shows a gain of twenty percent, from 154.362 million foot pounds per thousand pounds of steam in 1920 to 191.3 million foot pounds per thousand pounds of steam in 1925.

The fact that over 200 American Cities use De Laval centrifugal pumps of a total daily capacity of over 8,000,000,000 gallons, many of them purchased on repeat orders, is attributable to their high duty, low first cost, low cost for attendance and supplies, saving in building and foundation costs, and uninterrupted service.

If you are expecting to attend the 47th Annual Convention of the American Water Works Association, to be held in Chicago June 6th-11th, write for one of our large maps, showing the location of all points of interest, including pumping stations, in Chicago.

De Laval

Steam Turbine Co., Trenton, N.J.

LOCAL OFFICES: Atlanta, Boston, Charlotte, Chicago, Cleveland, Denver, Duluth, Havana, Helena, Honolulu, Houston, Indianapolis, Kansas City, Los Angeles, Montreal, New Orleans, New York, Philadelphia, Pittsburgh, Portland, Ore., St. Paul, Salt Lake City, San Francisco, Seattle, Spokane, Toronto, Vancouver 648



INTERNATIONAL

for Water Softeners

Each type of Zeolite Water Softener operates most efficiently when a particular grade of salt is used for regeneration.

Proceeding from this fact "International" has conducted exhaustive research and experiments. Now we are prepared to specify the salt which will enable your softener to give the best results.

There is no charge for this service. In writing please mention the type of softener in use in your plant.

**INTERNATIONAL
SALT COMPANY, Inc.**
475 Fifth Avenue, New York

Cleaning corroded pipes
and water mains pays big
dividends.

The cost is reasonable.

**General Pipe Cleaning
Company**

735 Commercial Trust Building
Philadelphia, Pa.

ADVERTISING

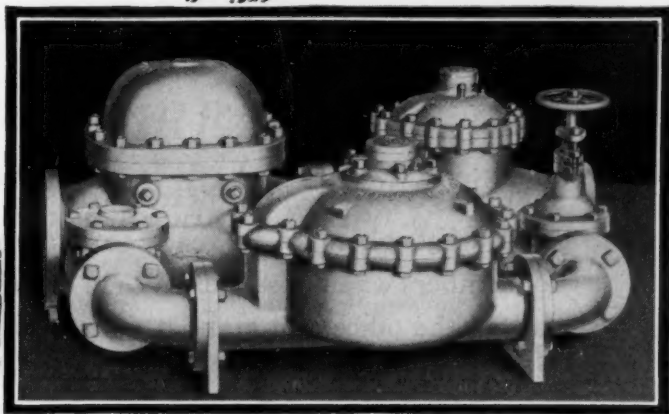
in this

JOURNAL

means more

BUSINESS

BILLIONS are Staked on the Dependability of *this* Meter



There is only one internally
balanced disc water meter.
That is the Hersey.

THE Hersey Detector Meter, for more than twenty years, has been accepted by every stock and mutual insurance company in the United States and over 800 water departments and water companies with absolutely no reservations.

The safety of billions of dollars of insured property value is staked on the dependability of this meter. It has never failed. It meets every requirement of a fire service meter. We shall be glad to send a catalog on request.

Hersey Manufacturing Company, South Boston, Mass.

HERSEY
WATER  **METERS**

NEW YORK, N. Y., 290 Broadway
PORTLAND, OREGON, 475 Hoyt St.
PHILADELPHIA, Pa., 314 Commercial Trust Bldg.
ATLANTA, GA., 510 Haas-Howell Bldg.

DALLAS, TEX., 2301 Griffin Street
CHICAGO, ILL., 10 So. LaSalle St.
SAN FRANCISCO, Cal., 690 Market St.
LOS ANGELES, Cal., 450 East Third St.

Main Office and Works: Corner E and 2nd Sts., South Boston, Mass.

NEW YORK OFFICE

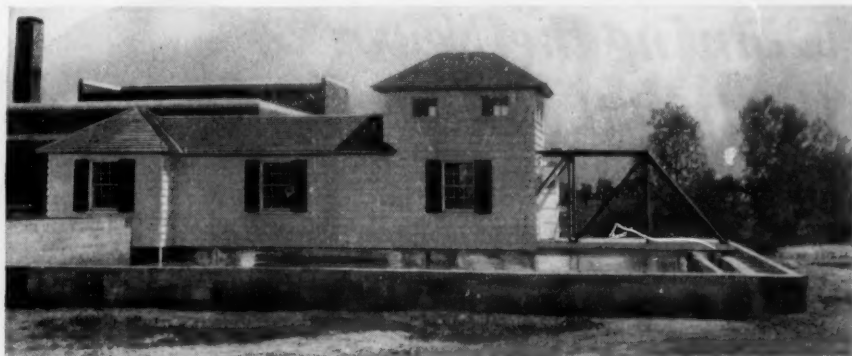
DON'T FORGET

that the Association has headquarters in New York City, where we are ready to be of service to members when possible. When in the City call at the office and make it your headquarters. Have your mail directed there if you have not made hotel reservations, and then come to the office for it, or advise where you wish it sent. Jot the address and telephone number down in your note book NOW, so as to have it when needed.

AMERICAN WATER WORKS ASSOCIATION

170 Broadway

Telephone Cortlandt 7718



Dorr Clarifier in the water softening plant at Piqua, O.

18 REASONS *for continuous sludge or silt removal in* **THE DORR CLARIFIER!**

Dorr Clarifiers have been included in the
water treatment plants of the following cities:

<i>Newark, O. Miami, Fla. Greenville, O. Springfield, Ill. Hinsdale, Ill. Piqua, O. Benton Harbor, Mich.</i>	<i>Kansas City, Mo. Lancaster, Pa. Decatur, Ill. Midland, Mich. Wausau, Wis. Blackwell, Okla. Wisconsin Rapids, Wis.</i>
--	--

and have also been installed by

<i>The South Pittsburgh Water Co., S. Pittsburgh, Pa. The Capital City Water Co., Jefferson City, Mo.</i>	<i>The Northwest Paper Co., Cloquet, Minn. The Texas Gulf Sulphur Co., Gulf, Texas</i>
---	--

Send for our Sanitary Engineering Bulletin

THE DORR COMPANY **ENGINEERS**

247 PARK AVENUE NEW YORK CITY

DENVER	LOS ANGELES	CHICAGO	WILKES-BARRE	JOPLIN
THE DORR CO. LTD	DORR G. m.b.H.	SOC. DORR ET CIE		
16 South Street London E.C.2	Joachimsthalerstr. 10, Berlin W.15	126, Rue de Provence Paris 8		
INVESTIGATION	TESTS	DESIGN	EQUIPMENT	

Winning the New- Holding the Old!

Each passing year shows a steady increase in the number of communities using Badger Meters.

And each passing year finds Badger Meters giving service in an ever widening territory.

This steady growth is a source of real satisfaction to us. It proves conclusively that Badger has the confidence of the water works industry—that Badger is being thoroughly tested through daily use—that it renders dependable service—that above all, Badger Engineering is *Right*.

Badger Meters are designed to perform a definite service—to do it *faithfully*, *dependably*, and at a *low maintenance cost*. The growth of this company in the past few years is the best proof we have of the worth of our product—the worth of our manufacturing and sales policies. Our guarantee is broad and is your assurance that you are dealing with a house that stands 100% behind its product.

If your lines are not Badger equipped, let us talk over your requirements with you. It will not obligate you in the least.

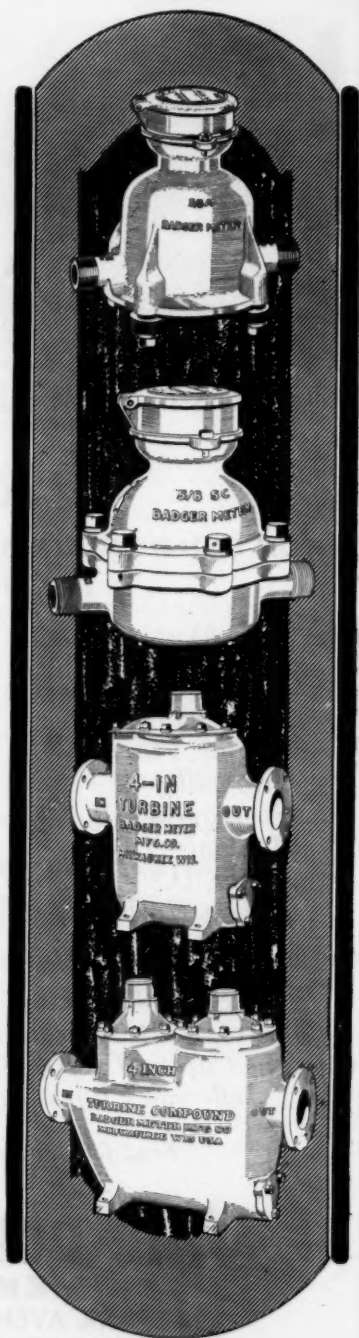
BADGER METER MFG. CO.

Milwaukee, Wis.

Branch Offices:

CHICAGO KANSAS CITY, MO. NEW YORK
111 W. Washington St. Interstate Bldg. 52 Vanderbilt Ave.

SEATTLE, WASH.
3136 Arcade Square



BADGER *Water* METERS

*over 4,500,000
made and sold the World over*

Lambert Meters

In 1890 Mr. John Thomson invented and began the manufacture of the original Lambert Water Meter, of which well over one million have been made and sold by the organization he founded, the Thomson Meter Corporation.

Trident Meters

In 1892 Mr. Thomson withdrew from the Thomson Meter Corporation founding the Neptune Company, redesigning and improving his original invention, producing the Trident Meter, of which over 3½ million have been made and sold.

Of these two famous Meters, over 4,500,000 have been sold. They are known the world over. They embody every noteworthy improvement in meter construction and operation. It is only logical that the two great present companies that created them should at last unite in a single greater organization (the largest water meter manufacturers in the world) joining experience and resources in the production of meters that may truthfully be described as

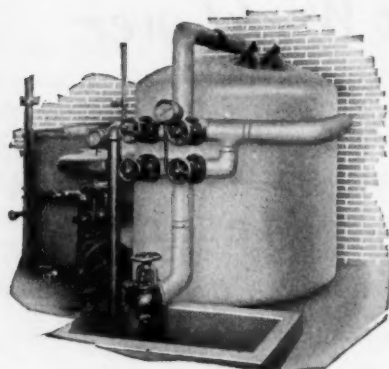
"The Cash Registers of the Water Works Field"



NEPTUNE METER COMPANY
THOMSON METER CORPORATION
 50 EAST 42ND STREET
 NEW YORK CITY
 FACTORY
 LONG ISLAND CITY, N.Y.
 PIONEERS IN METER PROGRESS



Don't Throw it Away



A Permutit Oil Removing Filter is scoured and cleaned like new at the turn of a few valves.

Reclaim Oily Returns and Save Wasted Fuel

Did you ever figure out how much money you could save by reclaiming your oily condensate instead of letting it run to waste? The figure will surprise you.

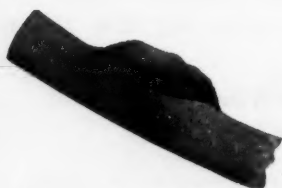
A boiler uses about 4 gallons of water per b.h.p. hour. If 75% condensate is available it would amount to 72,000 gallons per day of 24 hours for 1,000 b.h.p.—with condensate at 200°F. and makeup water at 70°F. this would be equivalent to 77,700,000 B.t.u. or approximately 9,750 lbs. of fuel, nearly 5 tons, about \$20.00 per day or \$6,000 yearly.

To make the calculation complete we should add to this the cost of softening the water and of blowoff which totals about 17-19 cents per 1,000 gals. or \$4,000 more per year. The total saving would therefore exceed \$10,000 per year for 1,000 b.h.p.

Heretofore it has not been easy to filter all the oil out of condensate, for the oil invariably exists both in suspension and emulsion, and ordinary filters will not do the work. They may remove the oil that is in suspension but emulsified oil is too finely divided and will pass right through usual filtering mediums.

Permutit Oil Removing Filters will take out all oil, both that in suspension and emulsion. They are compact and simple to operate and maintain. It is never necessary to remove or renew the filtering medium as in most other filters. They are guaranteed to deliver oil free water that is perfect for boiler feed.

It will pay you to know more about these filters. Write for our interesting booklet, "Saving Fuel and Repairs with Oil Free Feed Water." No obligations.



Section of a ruptured boiler tube caused by oil in the feed water.

The Permutit Company

Apparatus for Removing Impurities from Water

MONO-CAST PIPE

*weathers
bending
strains*



FLEXIBILITY and sturdiness have kept this old tree standing for years against strains and stresses that have destroyed its less adaptable fellows.

Flexibility, sturdiness and adaptability to service conditions enable MONO-CAST PIPE to absorb (and thereby withstand) shocks.

MONO-CAST PIPE is flexible and will therefore deliver service for many years.

This "bendability" is but one of the dozen points that recommend MONO-CAST to the thoughtful buyer.

**Costs Less to Buy
Costs Less to Lay**

Complete Engineering and
Cost Data on Request.



AMERICAN CAST IRON PIPE COMPANY

TRADE

REGISTERED IN U.S. PAT. OFF.

MARK

ACIPCO MONO-CAST PIPE
CENTRIFUGAL
B E L L A N D S P I G O T

THE FARNAN BRASS WORKS CO.

1104 Center St., Cleveland, Ohio

CORPORATION
AND
CURB STOPS



FOR LEAD PIPE
AND
IRON PIPE

For Copper Tubing
Special Brass Goods to Order

Established in 1852

NICHOLAS ENGEL

JOHN FOX & CO.

CAST IRON

WATER & GAS PIPES

FLANGE PIPE

Special Castings, Fire Hydrants, Valves

General Foundry and Machine Work

WOOLWORTH BUILDING

233 BROADWAY

NEW YORK CITY

POSITION WANTED

Water works manager or plant superintendent. Several years experience with pH correction in filter plant control, first class steam or electric construction and operating man; also familiar with outside construction and maintenance. Has A-1 record as regards operating costs and relations with the public. Age 42, employed, reason for desiring a change, wants larger job.

Inquire of Secretary's Office, 170 Broadway, New York, N. Y.

DON'T FORGET THE

GET A NEW MEMBER CAMPAIGN

SEND FOR APPLICATION BLANKS

AMERICAN WATER WORKS ASSOCIATION

170 BROADWAY, NEW YORK CITY

Removal Notice

On and after May 1, 1927, the Offices and Plant of this
Company will be located at

573 ELM STREET ARLINGTON, N. J.

(A suburb of Newark)

TELEPHONE KEARNY 3461

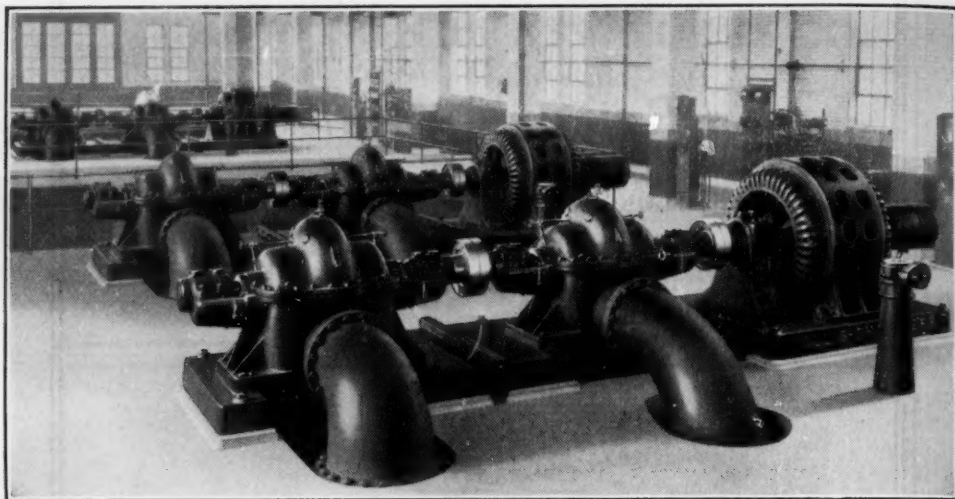
Larger quarters and other increased facilities will
enable us to render a more efficient service in the
maintenance, manufacture and sale of

PARADON CHLORINATORS

May we send you our latest bulletin?

PARADON MANUFACTURING COMPANY
ARLINGTON NEW JERSEY

Over 500 PARADON Chlorinators in service



3-20 M.G.D.-225 ft. head high service Allis-Chalmers Motor Driven Centrifugal Pumping Units installed in the Fridley Pumping Station, City of Minneapolis, Minnesota.

A RECORD EFFICIENCY

FOR 20 M.G.D. MOTOR DRIVEN CENTRIFUGAL PUMPING UNITS

The three Allis-Chalmers Combined Centrifugal Pumping Units, each consisting of a 1000 HP synchronous motor driving two 20" x 18" type SF Centrifugal Pumps connected in series, furnished for the City of Minneapolis were recently officially tested. The average combined efficiency obtained was slightly above eighty-four percent which so far as we know is a record efficiency for 20 M.G.D. 225 foot head motor driven centrifugal pumping units. It is performance of this kind which demonstrates the economy of Allis-Chalmers Pumping Equipment for municipal and other pumping purposes.

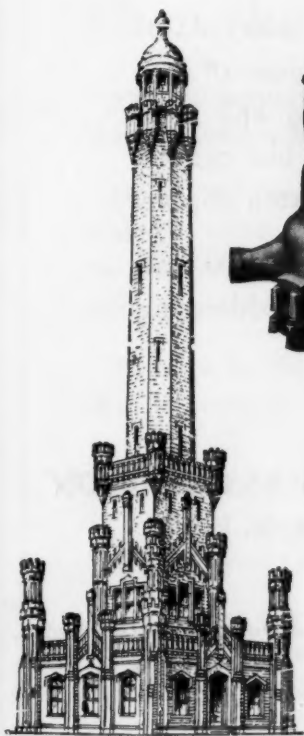
ALLIS-CHALMERS
MILWAUKEE, WIS. U. S. A.

TWO POINTS OF INTEREST AT THE A. W. W. A. CONVENTION

June 6 to 10

AT THE American Water Works Association Convention at Chicago, Ill., June 6th to 11th be sure to see the Chicago Water Tower and the Pittsburgh Equitable Meter Company Exhibit at the Hotel Sherman.

The headquarters of the Pittsburgh Equitable Meter Company will also be at the Hotel Sherman.



ARCTIC



TROPIC

Pittsburgh Equitable Meter Co.

Pittsburgh, Pa.

Branch Offices

New York, N. Y.

Chicago, Ill.

Dallas, Texas

Los Angeles, Cal.

Tulsa, Oklahoma

Seattle, Washington

Columbia, S. C.

Salt Lake City, Utah

Kansas City, Mo.

BADGES THE AMERICAN WATER WORKS ASSOCIATION



OFFICIAL BADGE

This cut is a facsimile, enlarged, of the official badge or emblem of the association. It is of gold and blue enamel made with a pin, but can be made into a button or watch charm.

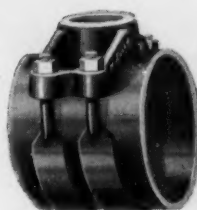
The price in solid gold is \$5.00 and they can be procured by addressing

AMERICAN WATER WORKS ASSOCIATION
170 Broadway, New York, N. Y.

**These badges are not to be confused with the usual convention badge,
but are for everyday use**



Mueller Drilling Machine, Model "E," drills holes one-half to one inch—in pipe of all sizes—under pressure. And does it with least wasted effort



Mueller Service Clamp, 10494, made of malleable iron, galvanized, provides a dependable, non-leaking connection. Integral-cast, patented lead gasket furnished with every clamp

When the work runs heavy—

—you will begin to appreciate the advantage of using this Mueller Drilling Machine.

Model "E" does the work better and in less time. It is simple, sturdy and finely built. It stands the abuse of the hardest job. It comes to you completely equipped and thoroughly tested.

Write us for further information about this and other Mueller products.

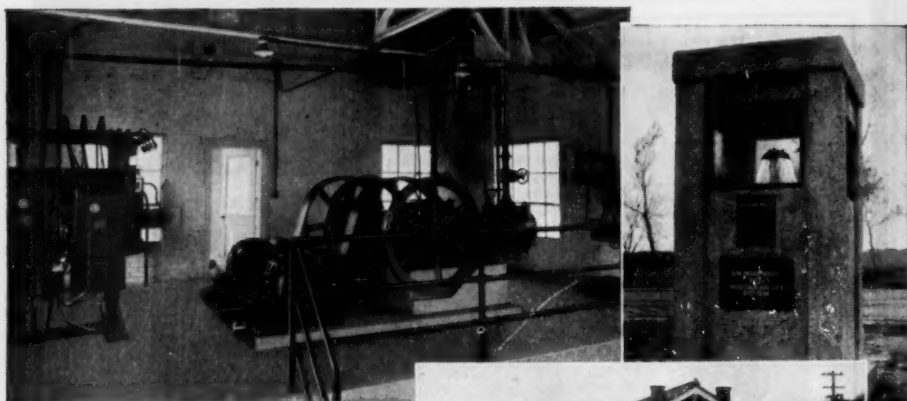
MUELLER CO. (ESTABLISHED 1857) DECATUR, ILL.

Branches: NEW YORK, SAN FRANCISCO, LOS ANGELES

Canadian Factory: MUELLER, LIMITED, SARNIA

MUELLER

dependable brass goods



Sullivan Air Lift Air Made Well Water Works at Chandler, Oklahoma. Two 11 x 10 "WG-6" Sullivan Compressors belted to electric motors, supply air for pumping 5 wells. The upper right cut shows one of the well heads with ornamental concrete stands. The substantial power house, receiving basin, and weir are shown below.

Air Made Wells Solve Chandler's Water Problem

Wells dug in the water sands at Chandler, Oklahoma, went dry. Seventy-one drilled wells fell off to less than 5 gallons per minute. Two consulting engineers said, "You cannot secure a dependable water supply from your shallow wells." Then a single Air Made Well and the Sullivan Air Lift System produced more water than 40 of the other wells—and its water flow is still increasing.

Chandler, like many other cities, has an abundant supply of water in beds of fine sand not far below the surface. But until Air Made Wells were put in, sand packing the walls of the dug wells, and choking the

screens of the drilled wells, prevented the city from utilizing the supply. The Mayor of Chandler had seen Air Made Wells and Sullivan Air Lift solve a similar problem at Tonkawa, and he investigated.

A test well pumped by Sullivan Air Lift was installed, and within one week it was supplying 56 gallons per minute. In 90 days it was furnishing 126 g.p.m.—and the water flow is still increasing. Chandler ordered four more Air Made Wells.

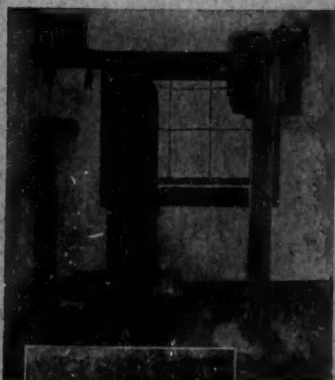
You too can make your shallow wells dependable, and secure the economies of a smaller pumping plant and smaller power cost of pumping.

GET CATALOG 4371-1

SULLIVAN MACHINERY COMPANY

136 S. MICHIGAN AVENUE, CHICAGO

All Well Waters —Should Be Chlorinated



The Elizabethtown Water Company, Elizabeth, New Jersey uses the new W & T Chlorinator, type M S P, to sterilize every drop of well water.

PUBLIC HEALTH ENGINEERS are rapidly dissipating the old-fashioned but popular idea that well waters are pure and safe to drink just because they are well waters and come from under-ground sources.

They know that well waters are liable to pollution—that a fissure in the rock or a break in the well casing often permits disease laden contamination to enter the supposedly pure water—particularly in times of flood.

They know that hundreds of Typhoid Fever Epidemics have been caused by well waters.—They know that the three outstanding typhoid epidemics in recent history—Salem, Ohio—Lansing, Michigan—Santa Anna, California—were all caused by polluted, *unchlorinated* well water.

That is why there is a marked tendency toward the chlorination of all well waters—because a properly chlorinated water cannot cause disease—because chlorination will not change the physical or chemical characteristics of the water in any way—because chlorination costing but one cent per capita per year is the cheapest public health insurance.

"The Only Safe Water is a Sterilized Water"



WALLACE & TIERNAN

COMPANY, INCORPORATED

Manufacturers of Chlorine Control Apparatus

NEWARK NEW JERSEY

NEW YORK CHICAGO KNOXVILLE SAN FRANCISCO MINNEAPOLIS PITTSBURGH DALLAS
KANSAS CITY LOS ANGELES SEATTLE ST. LOUIS BUFFALO HARRISBURGH INDIANAPOLIS
DETROIT WALLACE & TIERNAN, LTD., TORONTO, CANADA
WALLACE & TIERNAN, LTD., LONDON, ENGLAND

TWELVE REASONS WHY

YOU SHOULD USE

TRADE **"LEADITE"** MARK
REGISTERED U. S. PATENT OFFICE

FOR JOINTING C. I. WATER MAINS

- 1—Durability. Leadite joints improve with age. Leadite was tested out for 10 years before it was placed on the market, and has now been commercialised for more than 15 years, giving it a life of over 25 years.
- 2—No Caulking. Leadite joints require no caulking because the Leadite adheres to the pipe, making a water-tight bond.
- 3—Comparative Quantities. One pound of Leadite is equivalent to four pounds of lead because Leadite is so much lighter than lead.
- 4—Labor Saving. Saves caulking charges and digging of large bell-holes and reduces the cost of trench pumping to the minimum, facilitating rapid completion of the work.
- 5—Cost. Its use saves at least 50% to 75% over lead, owing to the saving effected in material and labor.
- 6—Tools. As no caulking is required, fewer tools are needed.
- 7—Transportation. Considerable freight charges are saved because Leadite is lighter than lead, and therefore you move only one-fourth the weight of jointing material.
- 8—Electrolysis. Leadite resists electrolysis. However, electrical thawing apparatus may be used for thawing out frozen mains or services.
- 9—Fuel. Saves fuel because you melt only one pound of material instead of four and not as much heat is required to melt Leadite as is needed to melt lead. Leadite will not explode or splutter when poured into wet or damp joints.
- 10—Delivery. We can make prompt shipments.
- 11—Damage Suits. Claims for damages caused by joints blowing out are prevented because Leadite joints will not blow out under any pressure.
- 12—Users. Progressive water works all over the country use Leadite and thousands of miles of pipe jointed with Leadite are in service.

Leadite is the pioneer self-caulking substitute for pig lead.

Be sure it is Leadite, and accept no imitations.

THE LEADITE COMPANY, Inc.
LAND TITLE BLDG. PHILADELPHIA

